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Founded by J. A. Nieuwland, C.S.C.

John D. Mizelle, Editor

CONTENTS

| | | |
|---|---|-----|
| A Memorial to Harley Jones Van Cleave..... | John D. Mizelle | 685 |
| A Review of the Coccidia from the Avian Orders Galliformes, Anseriformes and Charadriiformes, with Descriptions of Three New Species..... | Norman D. Levine | 696 |
| Studies on Monogenetic Trematodes. XIV. Dactylogyridae from Wisconsin Fishes..... | John D. Mizelle and A. Robert Klucka | 720 |
| Head Organs and Cephalic Glands of Cleidodiscus mirabilis..... | Theodore G. Brown, Jr. | 734 |
| Catenotaenia californica, sp. nov., a Cestode of the Kangaroo Rat,..... | Armstrong M. Dowell | 738 |
| Dipodomys panamintinus mohavensis..... | | |
| Rate of Development, Viability, Vigor, and Virulence of Ascaridia galli Ova Cultured Respectively in Air and in Water..... | M. F. Hansen, Ratana Oonyawongse, and J. E. Ackert | 743 |
| Studies on North American Fairy Shrimps with the Description of Two New Species..... | Ralph W. Dexter | 751 |
| Re-descriptions of Daphnia pulex var. pulicaria Forbes, D. thorata F. and D. dentifera F..... | John L. Brooks | 772 |
| A Study of the Population of Insects Emerging as Adults from the Dundas Marsh, Hamilton, Ontario, During 1948..... | W. W. Judd | 801 |
| Studies in the Malachiidae—IV..... | M. Y. Marshall | 825 |
| New Species in the Genera Dipogon Fox and Minagenia Banks (Hymenoptera: Psammocharidae) with Keys to Species and Photomicrographs of Genital Parts..... | R. R. Dreishach | 832 |
| The Orb-Weaving Spiders of the Chicago Area..... | Donald C. Lowrie | 846 |
| An Analysis of Stomach Contents of California Tide Pool Fishes..... | Donald F. Mitchell | 862 |
| Experiments on the Senses of Taste and Smell in the Bob-white Quail (Colinus virginianus virginianus)..... | Charles L. Hamrum | 872 |
| Seasonal Variation of Some Limnological Factors in Irondequoit Bay, New York..... | Willis L. Tressler, Thomas S. Austin and Edward Orban | 878 |
| A List of the Trees and Shrubs of the Indiana Dunes State Park..... | Kendall Laughlin | 904 |
| A Study of an Invasion by Red Maple of an Oak Woods in Southern Wisconsin..... | James A. Larsen | 908 |
| Revegetation of Alkali Flood Plains Adjoining the North Platte River, Garden County, Nebraska..... | Etlar L. Nielsen | 915 |
| Desmodium paniculatum (L.) DC. and D. viridiflorum (L.) DC..... | Duane Isely | 920 |
| Notes and Discussion..... | | |
| The Nieuwland Herbarium of the University of Notre Dame..... | | |
| A Report for the Period 1947-1952. I. | A. L. Delisle | 934 |
| Oryzococcus as a Genus..... | Frank C. Seymour | 935 |
| Book Reviews..... | | 936 |

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A Memorial to Harley Jones Van Cleave*

Dr. Harley Jones Van Cleave died on January 2, 1953, after suffering intensely from cancer for more than two years. He was born at Knoxville, Illinois, on October 5, 1886. He received his B.S. degree from Knox College at Galesburg, Illinois, in 1909. He entered the graduate school of the University of Illinois and received the degrees of M.S. in 1910 and Ph.D. in 1913. Immediately after receiving the doctorate he became a member of the staff of the Department of Zoology of the University of Illinois where he remained until his retirement in 1952. Dr. Van, as his students affectionately called him, was an indefatigable worker who led an extremely active life until confined to bed shortly before his death.

Dr. Van Cleave's life was devoted to the intellectual pursuits of teaching, research, administration, editing, and energetic membership in numerous honorary and learned societies. In addition to his activities at the University of Illinois during the regular school year, he was associated in the summer months as indicated by the following: Member of the staff of the Illinois State Normal University, 1913-15; Assistant, U. S. Bureau of Fisheries, 1919, 1921; Field Naturalist, Roosevelt Wildlife Experiment Station, 1928-34; Member of the staff of the Cold Spring Harbor Biology Laboratory, 1936; and of the Isle of Shoals Laboratory in 1939. Departmentally, he rose from instructor in 1913 to Professor of Zoology in 1929. He became Acting Head of the Department from 1938 to 1939 and was awarded a Research Professorship in 1948. He was elected president of the American Microscopical Society (1928) and was editor of the *Transactions* of this society from 1925 to 1931. He served as vice-president of the American Society of Parasitologists in 1935 and became president of this society for the year 1947. Later, in 1949, he was honored with the chairmanship of Section F of the American Association for the Advancement of Science. These are but a few of the positions of honor which he so ably held.

Dr. Van Cleave's publications in research are varied and numerous. In order to do him justice, a list of his works is given below. In addition to these publications he found time to publish 80 reviews on current volumes in biology.

Dr. Van Cleave was an inspiring teacher who was frank, friendly, and

* The author is greatly indebted to Dr. F. J. Kruidenier of the Department of Zoology, University of Illinois, for his assistance in assembling the bibliographical material in this article.



J. H. Vanleeuwen

one who appreciated and dispensed a good measure of wit and humor. His personal warmth in the classroom, laboratory, university halls, and at the national science meetings will be greatly missed by all who knew him.

The writer finds it impossible to refrain from adding a personal note concerning Dr. Van's association with *THE AMERICAN MIDLAND NATURALIST*. He was appointed by the author's predecessor as Associate Editor in Invertebrate Zoology in 1940, after a very careful survey of qualified men in this field. His broad knowledge which encompassed several fields of zoology together with his sound judgment and editorial discrimination, immediately made him most valuable to the journal and one who will be very difficult to replace. He was most helpful to the present editor who probably will feel his loss more acutely than workers and friends at large. It is with genuine wholeheartedness that *THE AMERICAN MIDLAND NATURALIST* and its present editor, salute Dr. Van Cleave as a great American scholar and also express a warm measure of gratitude for the privilege of having shared an association with him.—JOHN D. MIZELLE.

Scientific Publications of Harley Jones Van Cleave

1913

1. The Genus *Neorhynchus* in North America. *Zool. Anz.* 43:177-190.

1914

2. Studies on cell constancy in the genus *Eorhynchus*. *J. Morph.* 25:253-299.
3. *Eorhynchus*: a proposed new name for *Neorhynchus*. Hamann preoccupied. *J. Parasit.* 1:50-51.

1915

4. Factors concerned in the production of mitosis in organisms displaying cell constancy. *Biol. Bull.* 29:33-40.
5. Acanthocephala in North American amphibia. *J. Parasit.* 1:175-178.
6. Notes on biological methods from Univ. of Ill. *Trans. Amer. Micros. Soc.* 34:195-199.

1916

7. Distribution of grades in an elementary zoology course in the University of Ill. *Educ. Adm. and Superv.* 2:251-253.
8. Seasonal distribution of some Acanthocephala from fresh water hosts. *J. Parasit.* 2:106-110.
9. *Filicollis botulus* n. sp. with notes on the characteristics of the genus. *Trans. Amer. Micros. Soc.* 35:131-134.
10. A revision of the genus *Arhythmorhynchus*, with descriptions of two new species from North America. *J. Parasit.* 2:167-174.
11. Laboratory directions for an elementary course in general zoology. 72 pp. Lloyd's University Store, Champaign, Ill.
12. Acanthocephala of the genera *Centrorhynchus* and *Mediorhynchus* (new genus) from North American birds. *Trans. Amer. Micros. Soc.* 35:221-232.
13. Thomas Jonathan Burrill. *Ibid.* 35:279-280.

1917

14. Charles Zeleny on studies on the factors controlling the rate of regeneration. *Alumni Quart. and Fortn. Notes*, 11.
15. Charles Zeleny on studies on the factors controlling the rate of regeneration. *Minn. Alumni Weekly* 26:14.
16. The relative proficiency of university students in the elementary course in zoology. *School and Soc.* 5:356-360.
17. Observations on seasonal distribution and longevity of some Acanthocephala from fresh water hosts. *Trans. Ill. St. Acad. Sci.* 9:223-224.

1918

18. The Acanthocephala of North American birds (abstract). *Anat. Rec.* 14:103.
19. Acanthocephala of North American birds. *Trans. Amer. Micros. Soc.* 37:19-48.
20. The study of zoology as a factor in social and economic progress. *School and Soc.* 8:581-586.
21. The influence of high school biological courses upon grades of university freshmen in zoology. *School Sci. and Math.* 18:483-491.
22. Laboratory directions for an elementary course in general zoology. (revised edition). U. of Ill. Supply Store. 1-79.
23. *Centrorhynchus pinguis*, n. sp., from China. *J. Parasit.* 4:164-169.
24. Acanthocephala of the subfamily Rhadinorhynchinae from American fish. *Ibid.* 5:17-24.

1919

25. The field excursion in high school biological courses. *School Sci. and Math.* 19:7-10.
26. The study of zoology as a factor in social and economic progress. *Proc. Ill. H. S. Conf. for 1918*:113-118.
27. Acanthocephala from the Illinois River, with descriptions of species and a synopsis of the family Neoechinorhynchidae. *Bull. Ill. St. Nat. Hist. Survey* 13 Art. 8:225-257.
28. Acanthocephala from fishes of Douglas Lake, Michigan. *Occas. Papers. Mus. Zool. U. of Mich.* 72:1-12.

1920

29. Two new genera of Acanthocephala from Venezuelan fishes (abstract). *Anat. Rec.* 17:334.
30. Notes on the life cycle of two species of Acanthocephala from fresh water fishes (abstract). *Ibid.* 17:330.
31. Acanthocephala of the Canadian Arctic Expedition, 1913-1918. *Report. Canad. Arct. Exped. 1913-1918.* Vol. 9, part E:1-11.
32. Notes on the life cycle of two species of Acanthocephala from fresh water fishes. *J. Parasit.* 6:167-172.
33. Laboratory directions for an elementary course in general zoology. (third edition.) 86 pp. U. of I. Supply Store, Champaign, Ill.
34. John Lossen Pricer in his relation to natural science. *School Sci. and Math.* 20:652-654.
35. John Lossen Pricer. *Science (n.s.)* 52:242-243.
36. Two new genera and species of acanthocephalous worms from Venezuelan fishes. *Proc. U. S. Nat'l. Mus.* 58:455-466.
37. Sexual dimorphism in the Acanthocephala. *Trans. Ill. St. Acad. Sci.* 13:280-292.
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1921

39. Acanthocephala parasitic in the dog. *J. Parasit.* 7:91-94.
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41. Preliminary survey of the Acanthocephala from fishes of the Illinois River. *Ibid.* 12:151-156.
42. Acanthocephala collected by the Swedish Expedition to Joan Fernandy Islands (1916-1917). *Nat. Hist. of the Joan Fernandy and Eastern Islands.* Part 13:75-80.
43. Notes on the development and distribution of *Oncicola canis* (Kaupp, 1909) (abstract). *Anat. Rec.* 20:206.
44. Acanthocephala from the American eel (abstract). *Ibid.* 20:209.
45. Acanthocephala from the eel. *Trans. Amer. Micros. Soc.* 40:1-13.
46. Notes on two genera of ectoparasitic trematodes from fresh water fishes. *J. Parasit.* 8:33-39.

1922

47. A compendium of the hosts of animal parasites contained in Ward and Whipple's Fresh Water Biology. Trans. Amer. Micros. Soc. 40:195-199.
48. A determination of the degree of constancy in the nuclei of certain organs in *Hydatina senta*. Biol. Bull. 42:85-94.
49. A new genus of trematodes from the white bass. Proc. U. S. Nat'l Mus. 61:1-8.
50. Laboratory directions for an elementary course in general zoology (fourth edition). 92 pp. U. of I. Supply Store, Champaign, Ill.
51. A determination of the degree of constancy in the nuclei of certain organs in *Hydatina senta* (abstract). Anat. Rec. 23:102.
52. A new genus of trematodes from the white bass (abstract). *Ibid.* 23:115.

1923

53. Notes on Acanthocephala from Japan (abstract). Anat. Rec. 24:371.
54. *Telosestis*, a new genus of Acanthocephala from southern Europe. J. Parasit. 9:174-175.
55. Acanthocephala from the fishes of Oneida Lake, New York. Roosevelt Wild Life Bull. 2:73-84.
56. Acanthocephala from North American mammals (abstract). Anat. Rec. 26:355.

1924

57. Invertebrate zoology. i-xvi; 1-259. McGraw-Hill Book Co., N. Y.
58. A key to the genera of Acanthocephala. Trans. Amer. Micros. Soc. 42:184-191.
59. Some of the factors influencing distribution of animal parasites. Trans. Ill. St. Acad. Sci. 16:136-139.
60. Notes on the relationships of Acanthocephala (abstract). Anat. Rec. 29(4):119-120.

1925

61. A critical study of the Acanthocephala described and identified by Joseph Leidy. Proc. Acad. Nat. Sci. Phila. 76:279-334.
62. Additional notes on the Acanthocephala from America described by J. E. Kaiser (1893). Centralbl. f. Bakt., etc. I Abt. 94:57-60.
63. Laboratory directions for an elementary course in general zoology (fifth edition). 100 pp. U. of Ill. Bookstore, Champaign, Ill.
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65. Invertebrate zoology. American yearbook for 1925:924-926.
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69. Ctenophores as the host of a cestode. Trans. Amer. Micros. Soc. 46(3):214-215.
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73. Laboratory directions for an elementary course in general zoology (seventh edition). 102 pp. U. of Ill. Supply Store, Champaign, Ill.
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75. Two new genera and species of Acanthocephala from fishes of India. *Rec. Indian Mus.* 30(2):147-149.
76. The fairy shrimps of Illinois. *Trans. Ill. St. Acad. Sci.* 20:130-132.
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78. Nuclei of the subcuticula in the Acanthocephala. *Zeitschr. Wiss. Biol. Abt. B. Zeitschr. Zellforsch. u. Mikr. Anat.* 7(1):109-113.
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80. A textbook in general zoology (with Henry R. Linnville, and Henry A. Kelly). 463 pp., 234 figs. Ginn and Co., Boston.

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81. A new genus and new species of Acanthocephala from the Antarctic. *Ann. and Mag. Nat. Hist.* 4(20):229-231.
82. Our changing fauna. *Trans. Ill. St. Acad. Sci.* 21:26-36.
83. Studies on the life history of the blunt-nosed minnow (with Henry C. Markus). *Ibid.* 28:185.
84. Studies on the life history of the blunt-nosed minnow (with Henry C. Markus). *Amer. Nat.* 63(689):530-539.
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88. Stephen Alfred Forbes as a scientist. In memoriam Stephen Alfred Forbes (1844-1930). *Univ. of Ill. Press.* pp. 24-28.
89. Effects of drought. *Outdoor America.* Dec. 1930, 9(5):22-23.
90. Biological principles in general zoology. A laboratory manual (with H. R. Linnville and H. A. Kelly). Ginn and Co., Boston vi+185 pp.

1931

91. Acanthocephala from Japan. II. Two new species of the genus *Acanthocephalus*. *Annotationes Zool. Japonenses* 13(2):33-37.
92. Even the lowly. *Am. Game* 20(4):59.
93. Some of the biological effects of drought. *Sci. Monthly* 33:301-306.
94. The eggs and egg-laying habits of snails of the genus *Pleurocera*. *Anat. Rec.* 51(1):77-78.
95. *Heterosentis*, a new genus of Acanthocephala. *Zool. Anz.* 93(5/6):144-146.
96. Invertebrate zoology (second edition). 282 pp., 126 figs. McGraw-Hill Book Co., N. Y.
97. Acanthocephala in North American amphibia. II. A new species of the genus *Acanthocephalus*. *Trans. Amer. Micros. Soc.* 50(1):46-47.
98. New Acanthocephala from fishes of Mississippi and a taxonomic reconsideration of forms with unusual numbers of cement glands. *Ibid.* 50(4):348-363.
99. Some of the biological effects of drought. *Sci. Monthly* 33(4):301-306.
100. The systematic position of some trematodes from fresh water fishes of North America (with J. F. Mueller). *J. Parasit.* 18(2):132-133.
101. What is *Diplostomulum scheuringi* (abstract) (with J. F. Mueller). *J. Parasit.* 18(2):126.
102. A comparative study of certain species of fairy shrimps belonging to the genus *Eubranchipus* (with Sister Stella Maria Hogan). *Trans. Ill. St. Acad. Sci.* 23(3):284-290.

1932

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104. Statistical analysis of quantitative collections as a means of interpreting life histories. Trans. Ill. St. Acad. Sci. 24(2):228-234.
105. Eutely or cell constancy in its relation to body size. Quart. Rev. Biol. 7(1):59-67.
106. Studies on the life cycle of the snail, *Viviparus contectoides* (with Ludwig G. Lederer). J. Morph. 53(3):499-522.
107. Parasites of the Oneida Lake fishes. I. Descriptions of new genera and new species (with J. F. Mueller). Roosevelt Wild Life Ann. 4(3):5-71.
108. Parasites of Oneida Lake fishes. II. Descriptions of new species and some general taxonomic considerations, especially concerning the trematode family Heterophyidae (with J. F. Mueller). *Ibid.* 3(2):77-137.

1933

109. An amphibious habitat on vertical sandstone cliffs. Ecology 14(2):149-151.
110. An index to the International Rules of Zoological Nomenclature. Trans. Amer. Micros. Soc. 52(4):322-325.
111. An analysis of some of the factors influencing the rate at which species have been described. Copeia 1933(2):68-73.
112. Zoology in the Junior College curriculum. Junior Coll. Jour. 3(5):255-259.
113. Studies on snails of the genus *Pleurocera*. II. The young of *P. acuta*. Nautilus 47(2):48-49.

1934

114. Natural vs. accidental death in different habitats of the snail *Viviparus contectoides*. Trans. Ill. St. Acad. Sci. 26(3):136.
115. Length of life span as a factor in regulating populations. Ecology 15(1):17-23.
116. Observations on the status of certain genera of Acanthocephala, chiefly from birds (abstract). J. Parasit. 20(6):324.
117. Studies on the life cycle and reversal of symmetry in a fresh water snail, *Campeoloma rufum* (abstract). Anat. Rec. 60(4):94-95.
118. Parasites of Oneida Lake fishes. III. A biological and ecological survey of the worm parasites (with Justus F. Mueller). Roosevelt Wild Life Ann. 3(3/4):161-334.

1935

119. Seasonal life history of a snail of the genus *Fossaria* (abstract). Trans. Ill. St. Acad. Sci. 27(2):161.
120. Man meddles with nature. Sci. Monthly 40:339-348.
121. Invertebrates in their relation to man. Gamma Alpha Record 25(2):47-50.
122. The larval stage of Acanthocephala (abstract). J. Parasit. 21(6):435-436.
123. The seasonal life history of an amphibious snail, *Fossaria modicella*, living on sandstone cliffs. Ecology 16(1):101-108.
124. Studies on the life history of a snail of the genus *Lioplax* (with Ray Chambers). Amer. Midl. Nat. 16(6):913-920.

1936

125. A tentative survey of the classification of the Acanthocephala (multigraphed).
126. Some interesting pre-Linnaean names. Trans. Ill. St. Acad. Sci. 28(2):263-265.
127. *Tenuisentis* a new genus of Acanthocephala, and its taxonomic position. Parasitology 28(3):446-451.
128. The recognition of a new order in the Acanthocephala. J. Parasit. 22(2):202-206.
129. Fresh water jellyfishes in Illinois. Science 83(2158):443.
130. Reversal of symmetry in *Campeoloma rufum*, a fresh water snail. Amer. Nat. 70:567-573.
131. Acanthocephala from amphibians and reptiles of China (abstract). J. Parasit. 22(4):530.
132. Studies on the radula in snails of the genus *Viviparus* (with Emily McDavid Richey). Trans. Amer. Micros. Soc. 55(2):223-229.
133. On the assignment of *Echinorhynchus dirus* to the genus *Acanthocephalus* (with Lee H. Townsend). Proc. Helm. Soc. Washington 3(2):63.

1937

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139. Helminthology in wild life investigations. Jour. Wildlife Management 1(1):21-27.
140. When man meddles with nature. Sci. Digest 2(5):27-30.
141. Opportunities in biology. Bios 8(3):117-121.
142. Status of the generic name *Profilicollis* of A. Meyer (abstract). J. Parasit. 23(6):563.
143. Studies on the life cycle of *Campelema rufum*, a fresh water snail (with Dorothy A. Altringer). Amer. Nat. 71(733):167-184.
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1938

145. Thural Dale Foster (Sept. 27, 1897-June 6, 1936). Nautilus 51(2):62-63.
146. Invertebrates in their relation to man. Bios 9(1):14-20.
147. Variability in hook measurements in the Acanthocephala. J. Parasit. 24(6):25.

1939

148. Animals in their relation to disease. Bios 10(1):42-47.
149. A new species of the acanthocephalan genus *Polymorphus* and notes on the status of the name *Profilicollis*. J. Parasit. 25(2):129-131.
150. An analysis of hook measurements in the Acanthocephala. Vol. Jubilar por Prof. Sadas Yoshido Vol. II:331-337.
151. The phylogenetic relations of the Acanthocephala (abstract). Abstr. of Communications, Third Internatl. Congress of Microbiol. N. Y. Sept. 2-9, 1939:168.
152. Systems for designating hook patterns in the Acanthocephala (abstract). J. Parasit. 25(6):10.
153. A reconsideration of the acanthocephalan family Rhadinorhynchidae (with D. R. Lincicome) (abstract). *Ibid.* 25 (suppl.):1.
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A Review of the Coccidia from the Avian Orders Galliformes, Anseriformes and Charadriiformes, with Descriptions of Three New Species

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In the summer of 1949, Harold C. Hanson of the Illinois State Natural History Survey took part in the Perry Expedition which was carried out under the auspices of the Arctic Institute of North America with funds furnished by the Office of Naval Research. The Perry River opens onto Queen Maud Gulf in the Arctic Ocean close to the dividing line between the districts of Mackenzie and Keewatin in the Canadian Northwest Territories, at approximately 102° W. longitude and 68° N. latitude.

During this trip Mr. Hanson collected fecal samples or intestinal contents from 49 wild birds of 21 species. The results of the study of this material are presented herein.

In order to determine the taxonomic position of the coccidia found in these birds, a critical review of the literature was found necessary. Many species have been described since Becker's (1934) book and Boughton and Volk's (1938) review. While Hardcastle's (1943) checklist includes many of these, it does not give morphological data, nor does it give the presently accepted scientific names of the hosts. Furthermore, since many workers named new species without adequate reference to previous or contemporary work, the validity of some species may be open to question. Finally, it is hoped that a summary of the data on morphology and host-parasite relationships may serve as a starting-point for and guide to future work.

All bird names in this paper have been checked with the American Ornithologists' Union *Check-list of North American birds* (1931 and subsequent supplements) or with Peters' (1931-1948) *Check-list of the birds of the world*. I should like to thank Dr. Harvey I. Fisher, Department of Zoology, University of Illinois, and Dr. Ernst Mayr, American Museum of Natural History, New York, for information on certain points of nomenclature.

Since all of the expedition's supplies had to be flown in, weight and bulk were important factors in determining the collecting methods used for fecal material. Most of the fecal samples were therefore collected in 15-25 ml. screw-cap vials. Before the vials were packed for the trip a line was marked on them to indicate $\frac{3}{4}$ of their capacity. Sufficient concentrated potassium bichromate solution was added so that if additional water were added to the line, a 2½% solution would result. The concentrated potassium bichromate solution was then evaporated to dryness for transportation. When the vials were used, water was added to the line, the bichromate was dissolved, and a small amount of

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feces added. Prior to examination in the laboratory several months later, the total contents of each vial were mixed well, placed in a petri dish, and allowed to incubate for a week or more at room temperature. The material was then examined microscopically both directly and after sugar flotation.

The results of the examinations for coccidia are summarized below. A brief abstract of the findings has been published by Levine and Hanson (1950).

| | Number Examined | Number Positive |
|---|--------------------|--------------------|
| Order Anseriformes | | |
| Family Anatidae | | |
| Subfamily Anserinae | | |
| <i>Anser albifrons</i> (white-fronted goose) | 5 | 0 |
| <i>Branta canadensis parvipes</i> (lesser Canada goose) | 4 | 1 |
| <i>Branta bernicla nigricans</i> (black brant) | 3 | 0 |
| <i>Chen caerulescens</i> (blue goose) | 1 | 1 |
| <i>Chen rossii</i> (Ross goose) | 6 | 0 |
| Subfamily Nyrociniae | | |
| <i>Clangula hyemalis</i> (old squaw duck) | 3 | 1 |
| <i>Somateria spectabilis</i> (king eider) | 4 | 0 |
| Order Charadriiformes | | |
| Suborder Charadrii | | |
| Superfamily Charadrioidae | | |
| Family Charadriidae | | |
| Subfamily Charadriinae | | |
| <i>Charadrius hiaticula semipalmatus</i> (semipalmated plover) .. | 1 | 0 |
| <i>Squatarola squatarola</i> (black-bellied plover) | 1 | 0 |
| Subfamily Arenariinae | | |
| <i>Arenaria interpres morinella</i> (ruddy turnstone) | 1 | 1 |
| Family Scolopacidae | | |
| Subfamily Calidridiinae | | |
| <i>Erolia melanotos</i> (pectoral sandpiper) | 1 | 0 |
| <i>Erolia fuscicollis</i> (white-rumped sandpiper) | 2 | 0 |
| Suborder Lari | | |
| Family Stercorariidae | | |
| <i>Stercorarius parasiticus</i> (parasitic jaeger) | 1 | 0 |
| <i>Stercorarius longicaudus</i> (long-tailed jaeger) | 1 | 0 |
| Family Laridae | | |
| Subfamily Larinae | | |
| <i>Larus hyperboreus hyperboreus</i> (glaucous gull) | 1 | 0 |
| <i>Larus argentatus smithsonianus</i> (herring gull) | 2 | 0 |
| <i>Xema s. sabini</i> (sabine gull) | 3 | 0 |
| Subfamily Sterninae | | |
| <i>Sterna paradisaea</i> (Arctic tern) | 1 | 0 |
| Order Gaviiformes | | |
| Family Gaviidae | | |
| <i>Gavia stellata</i> (red-throated loon) | 1 | 0 |
| Order Gruiformes | | |
| Family Gruidae | | |
| <i>Grus canadensis canadensis</i> (little brown crane) | 1 | 0 |
| Order Galliformes | | |
| Superfamily Phasianoidae | | |
| Family Tetraonidae | | |
| <i>Lagopus mutus rupestris</i> (rock ptarmigan) | 6 | 2 |
| Total | 49 | 6 |

In addition, trematode eggs were seen in one old squaw duck (*Clangula hyemalis*); cestode eggs were seen in one old squaw duck, one blue goose (*Chen caerulescens*), one sabine gull (*Xema sabini*), and one Arctic tern (*Sterna paradisaea*); and stronglylid type nematode eggs were seen in one blue goose.

The coccidia found in these birds are described below.

Order ANSERIFORMES

Eimeria brantae n. sp.

A moderate number of unsporulated coccidian oocysts were found in the feces of one out of four lesser Canada geese, *Branta canadensis parvipes*. The suspension was set aside for three weeks to see whether sporulation would take place. At the end of this time a single sporulated oocyst containing four sporocysts, each with two sporozoites, was seen. This established the genus as *Eimeria*. The suspension was set aside for a further period, but no more oocysts sporulated. A detailed study was not made of the single sporulated oocyst, so no further morphological data can be given on it.

An unsporulated oocyst is shown in Fig. 1. The oocysts were slightly ovoid in shape, with a distinct micropyle at the smaller end. No refractile granule was seen in the unsporulated oocysts. The oocyst wall was composed of two colorless layers, the outer layer being slightly thicker than the inner. The inner layer was markedly thickened around the micropyle. A typical cocyst measured 17.7 by 23.4 microns, with a length-width index of 1.3. The sporont measured 14.2 by 17.7 microns.

Data on the coccidia described from members of order Anseriformes are given in Table 1. Some additional information is given by Becker (1934, 1948). The literature on coccidiosis of domestic geese is reviewed by Levine, Morrill and Schmitz (1950).

The *Eimeria* found in *Branta canadensis parvipes* differs morphologically from the other coccidia reported from the Anseriformes. It lacks the characteristic thick lips around the micropyle of *Eimeria magnalabia*. It is larger than *Eimeria parvula* and has a micropyle which this species lacks. It differs from *E. nocens* in that its wall is colorless, and it is not flat at the micropylar end. It differs in shape from both *E. anseris* and *E. truncata*; the former is distinctly pyriform, and the small end of the latter is rather narrow, while the form from *Branta canadensis* is smoothly ovoid.

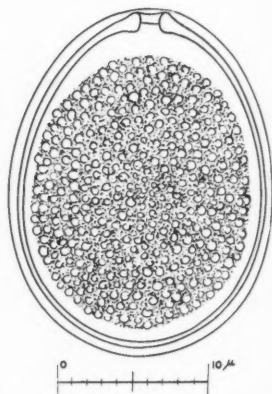


Fig. 1.—*Eimeria brantae* unsporulated oocyst $\times 4000$.

Its length-width ratio of 1.3 is

much less than the mean length-width ratio of 2.0 reported for *E. bucephalae*. Furthermore, the inability of Christiansen and Madsen (1948) to transmit *E. bucephalae* from the goldeneye to the tufted duck, *Nyroca* (= *Aythya*) *fuligula* suggests that it is even less likely that this species would be transmissible to the more distantly related Canada goose. In view of these differences, and even though the data are sparse, it is felt justifiable to assign to it a new specific name as a matter of convenience. Hence I am naming it *Eimeria brantae* n. sp.

EIMERIA (?) or TYZZERIA (?) sp.

In one out of three old squaw ducks, *Clangula hyemalis*, a few unsporulated, probably degenerating oocysts were observed in a flotation preparation. They were ellipsoidal; no micropyle was seen. A refractile granule was seen in only one oocyst. There was relatively little space between the sporont and the oocyst wall. Five oocysts measured 9.5-11.0 x 10.7-15.5 microns, with a mean of 10.5 x 13.3 microns. The length-width index ranged from 1.1 to 1.3, with a mean of 1.2. It is of course impossible to name this coccidium, but the characters observed are not inconsistent with those of *Eimeria parvula* Kotlán, 1933 which was described from the domestic goose, *Anser anser*, or with those of *Tyzzeria*. The additional possibility that it may belong to still another genus cannot be excluded.

A few similar very small unsporulated oocysts were seen in a flotation from the blue goose, *Chen caerulescens*. No measurements were made. The suspension was set aside in the hope that the oocysts would sporulate. Three weeks later they still had not done so, and a week later the preparation had dried out.

Order CHARADRIIFORMES

EIMERIA (?) sp.

Numerous unsporulated coccidian oocysts were observed from a single adult ruddy turnstone, *Arenaria interpres morinella*. Most of the oocysts were degenerate at the time of examination, three months after collection. Since none sporulated, it was impossible to determine the genus to which they belonged. The oocysts were ellipsoidal; three measured 15.5-16.6 x 22.6-25.0 microns (mean 15.9 x 23.8 microns). Their length-width index was 1.5.

The only coccidian species so far described from the order Charadriiformes are *Eimeria roscoviensis* (Labbé, 1893) Wasielewski, 1904 and *E. meservei* Coatney, 1935. The latter was reported from Forster's tern, *Sterna forsteri*. The oocysts of *E. meservei* are spherical to subspherical, measure 14.5-18 x 16.2-19.4 microns (mean 16.8 x 17.7 microns), contain both oocysts and sporocyst residual bodies, and have a refractile granule and a micropyle. The sporont almost fills the unsporulated oocyst. The sporocysts are long and slender.

Labbé (1893, 1896) reported *E. roscoviensis* from the Kentish plover, *Charadrius a. alexandrinus* (= *C. cantianus*); the little ringed plover, *Charadrius dubius curonicus* (= *C. philippinus*); the turnstone, *Arenaria* (= *Strep-*

silas) *interpres*; the sanderling, *Crocethia alba* (= *Calidris arenaria*); the dunlin, *Erolia* (= *Tringa*) *alpina*; the sandpiper, *Calidris alpina schinzii* (= *Pelidna torquata*); the sandpiper, *Actitis hypoleucos*; the whimbrel, *Numenius phaeopus*; the European golden plover, *Pluvialis apricaria*; the redshank, *Tringa totanus* (= *Totanus calidris*); and also from the cormorants, *Phalacrocorax aristotelis* (= *P. cristatus*), of the order Pelicaniformes and the European white wagtail, *Motacilla alba*, of the order Passeriformes.

According to Labbé, the oocysts of *E. roscoviensis* measure 14-16 x 16-18 microns, and are pyriform, with a very thin wall. One end is drawn out into a short truncated "neck." The flat top thus formed Labbé termed a pseudomicropyle. The young oocysts are often greenish or yellowish green. Two refractile granules are present in the oocyst. There is no oocyst residual body. The sporocysts are pyriform, with a thickened knob at the small end. Each contains two curved sporozoites and a residual body.

While the sporulated oocyst figured by Labbé (1896) is pyriform, the three unsporulated oocysts also figured by him are not pyriform but ellipsoidal, and have a length-width index of approximately 1.5. Hoare (1933) has described a transition from an ellipsoidal unsporulated oocyst to a pyriform sporulated one in *Eimeria urnula* from the cormorant, *Phalacrocorax carbo lugubris*. Hence it is quite possible that the coccidium I observed from *Arremonia interpres morinella* may have been *Eimeria roscoviensis*.

It is rather unlikely that *E. roscoviensis* would occur in such a distantly related genus as *Motacilla*. Whether it also occurs in *Phalacrocorax* is perhaps also doubtful. Although it was rather similar to *E. roscoviensis*, Hoare (1933) considered the form which he found in *P. carbo lugubris* to be sufficiently different to be a different species, *E. urnula*. Perhaps Labbé saw this form in *P. aristotelis* and considered it *E. roscoviensis* because of its similarity. Further work will be needed to determine the true situation.

Order GALLIFORMES

Before describing the coccidia observed in the rock ptarmigan, it is necessary to review the species which have already been described from the order Galliformes. This has not been done since Becker's (1934) book, the review by Boughton and Volk (1938) and Hardcastle's (1943) list. Since then several new species have been described. Boughton and Volk (1938) listed only 34 species of *Eimeria* from all birds. At present one species of *Cryptosporidium*, 30 of *Eimeria*, 2 of *Isoospora* and 2 of *Wenyoniella* have been described from the order Galliformes alone. Their principal characteristics are given in Table 2.* Except for the chicken and turkey species, little is known of the physiological characteristics and host-parasite relationships of these coccidia.

In naming new species of coccidia, morphological, host-parasite, and immunological characteristics should be considered. It is clear from the table that

* Because I may not have seen some recent papers, some species may have been inadvertently omitted. I should appreciate being informed of these. In this connection, the Brazilian "perdiz," *Rhynchotus rufescens*, from which Reis and Nobrega (1936) described *Eimeria rhynchoti*, is not a quail or partridge, but a tinamou (Order Tinamiformes).

many of the morphological features of many species have not been described. In addition, many investigators described new species without reference to all the species previously described from the same or related hosts.

The different species of the genus *Eimeria* are usually markedly host-specific. Hence, in the absence of valid cross-infection experiments, it is unwise to assign the same specific name to morphologically similar forms from hosts which are not closely related. Furthermore, morphologically similar forms from the same host may be immunologically different, and thus be justifiably considered different species, as Johnson (1938) and P. P. Levine (1938, 1942) have shown in the chicken.

Of the species listed in Table 2, the name *Eimeria avium*, used by Fantam (1910) for coccidia from the red grouse, *Lagopus scoticus*, by Brinkmann (1926) for coccidia from the willow ptarmigan, *Lagopus lagopus*, the ptarmigans, *Lagopus mutus* and *L. mutus hyperboreus*, the capercaillie, *Tetrao urogallus*, and the black grouse, *Lyrurus tetrrix*, is incorrect. Prior to the appearance of Tyzzer's (1929) paper, this name was used indiscriminately for many avian coccidia, and is no longer accepted as valid. In addition to these authors, Verwey (1926) saw coccidia in the grey partridge, *Perdix perdix*, and in the pheasant, but believed that most birds were infected with a single species.

Yakimoff and Gousseff (1936) described *Eimeria lyruri* Galli-Valerio, 1927 from the black grouse, *Lyrurus tetrrix*, the capercaillie, *Tetrao urogallus*, and the woodpecker, *Dendrocopos* (= *Dryobates*) *major*. They also described *E. yakisevi* (Yakimoff and Gousseff, 1936) Hardcastle, 1943 (= *E. brumpti* Yakimoff and Gousseff, 1936), from *Tetrao urogallus* and the same woodpecker. In view of the relatively narrow host range encountered in the genus *Eimeria*, it is extremely unlikely that the same species would occur in such different orders as the Galliformes and the Piciformes. Hence, since no experimental evidence supports Yakimoff and Gousseff's view, I think the forms in the two orders belong to different species. I therefore assign the name, *Eimeria dendrocopi* nom. nov. to the species which they described from *Dendrocopos* (= *Dryobates*) *major* under the name, *Eimeria lyruri*, and the name, *Eimeria nonbrumpti* nom. nov. to *E. yakisevi* (= *E. brumpti*) from the same host.

Much remains to be learned about the host specificity of most of the coccidia of the Galliformes. Relatively few cross-infection studies have been carried out, especially with the wild bird parasites, and some of the results which have been reported are open to grave criticism. The results of cross-infection experiments are summarized in Table 3.

Henry (1931) reported three chicken species, *Eimeria tenella*, *E. acervulina* and *E. mitis*, from the California quail, *Lophortyx c. californica* (= *L. c. vallicola*) and the mountain quail, *Oreortyx picta*. She claimed to have transmitted all three species to chickens. However, Herman (1949) reported that several attempts to transmit to chickens four of the five species of coccidia which occur in the California valley quail were unsuccessful. Herman did not name the species which occur in this host; they have not yet been adequately described. In view of Herman's findings, it is rather unlikely that *E. tenella*, *E. acervulina* and *E. mitis* occur in either *Lophortyx c. californica* or *Oreortyx picta*. The species which do occur in these hosts remain to be determined.

The situation with regard to the bobwhite quail, *Colinus virginianus*, is only slightly better. Three species of *Eimeria* have been described from this host. Venard (1933) stated that the chicken species, *E. tenella* and *E. acervulina*, occurred in the bobwhite, and claimed to have transmitted *E. tenella* from the quail to two chicks. He failed to transmit *E. acervulina* from this quail to chicks. On the other hand, Tyzzer (1929) was unable to transmit *E. acervulina* from the chicken to the quail, and Patterson (1933) failed to infect quail with *E. tenella*, *E. acervulina*, *E. mitis* or *E. maxima* from the chicken. The third species, *E. dispersa*, was described by Tyzzer (1929) from the quail and pheasant. He transmitted it from the quail to the turkey, chicken (slight infections in 6 out of 12 birds) and probably pheasant, and from the pheasant to the quail. Venard (1933) found *E. dispersa* in the bobwhite, but was unable to transmit it to chickens. Patterson (1933) failed to infect chickens with *E. dispersa* from the quail. Hawkins (1951) found *E. dispersa* in turkeys, and transmitted it to the bobwhite quail, Hungarian partridge and pheasant.

I conclude from the above reports that several species of *Eimeria* occur in *Colinus virginianus*, that one of them is *E. dispersa*, which is transmissible to the turkey, pheasant and slightly to the chicken, and that *E. acervulina* and *E. tenella* probably do not occur in this host. A thorough study of the coccidia of the bobwhite quail is needed.

Two species of coccidia, *E. angusta* and *E. centroceri*, have been described from the sage hen, *Centrocercus urophasianus*, although Honess (1942) believes there may be more. Both Simon (1939) and Honess (1942) failed to transmit these species to the chicken.

Six species of *Eimeria* have been described from the ring-necked pheasant, *Phasianus colchicus*: *Eimeria dispersa*, *E. langeroni*, *E. megalostomata*, *E. pacifica*, *E. phasiani*, and *E. tenella*. In addition, Ormsbee (1939) described an *Eimeria* sp. which does not appear to belong to any of these species. Although Haase (1939) reported *E. tenella* from both *Phasianus colchicus colchicus* and *P. c. torquatus*, he did not carry out cross-infection experiments with chickens. Tyzzer (1929) failed to infect the chicken, turkey or bobwhite quail with *E. phasiani* from the ring-necked pheasant, and Patterson (1933) failed to infect chicks with the same species.

The relationship of some of the species in turkeys and chickens should also be mentioned. Although Henry (1931) claimed to have infected chickens with turkey coccidia whose oocysts were identical with those of *E. acervulina* and *E. tenella*, Tyzzer (1929) was unable to infect the chicken, pheasant or bobwhite quail with *E. meleagridis* from the turkey, and Johnson (1923) was not able to infect one turkey with coccidia from the chicken. Hawkins (1952) failed to infect the bobwhite quail and Hungarian partridge with either *E. meleagridis* or *E. meleagritidis* from the turkey. On the other hand, Steward (1947) stated that he succeeded in infecting chickens with *E. meleagridis* from the turkey, and back-infected turkeys with oocysts from the chickens. However, he failed to infect one turkey with *E. acervulina*

from the chicken. The transmissibility of *E. meleagridis* between turkey and chicken thus remains in doubt. Moore and Brown (1951, 1952) were unable to transmit *E. adenoides* and *E. innocua* from the turkey to the chicken, guinea fowl, pheasant or quail.

COCCIDIA OF THE ROCK PTARMIGAN

Eimeria oocysts were found in two of the six rock ptarmigans (*Lagopus mutus rupestris*) examined. The forms in the two birds differed morphologically, and appeared to belong to different species. Brinkmann (1926) reported "*Eimeria avium*" from *Lagopus mutus* and *Lagopus mutus hyperboreus* in Norway, but he was probably dealing with a mixture; in any case, for reasons already given, this specific name is unacceptable. Galli-Valerio (1929) described *Eimeria lagopodi* from *Lagopus mutus* in Switzerland. His description is so brief and omits so many morphological characters that it may be difficult for future taxonomists to determine what species he was dealing with. Both the species encountered in the Perry River ptarmigan somewhat resemble *E. lagopodi*. However, Galli-Valerio stated that this species has a micropyle, although a scarcely visible one. No micropyle could be discerned in either Perry River form. The two Perry River coccidia did not closely resemble any species previously described from other members of the family Tetraonidae. Hence it seems best to consider them both to be new species.

Eimeria brinkmanni n. sp.

Fig. 2

This species was found in one of the six rock ptarmigans (*Lagopus mutus rupestris*) from the Perry River Region of the Canadian Arctic. Ten oocysts measured $18.0-19.6 \times 26.0-29.7$ microns, with a mean of 18.8×28.6 microns. Their length-width ratio varied from 1.4 to 1.6, with a mean of 1.52. They were ellipsoidal in shape. No micropyle was present. The sporulated oocysts contained four sporocysts and one or two refractile granules. In most cases these granules were polar or sub-polar, but in two of the ten they were central. No oocyst residual body was present. The oocyst wall was composed of two layers, the outer layer being relatively thick, brownish yellow and slightly rough. The inner layer was relatively thin and colorless. The pyriform sporocyst measured approximately 13×7 microns, and had a rather large Stieda body or "knob" at the small end. Each contained two sporozoites lying side by side with the large end of one next to the small end of the other. No sporocyst residual body was present. I am naming this species *Eimeria brink-*

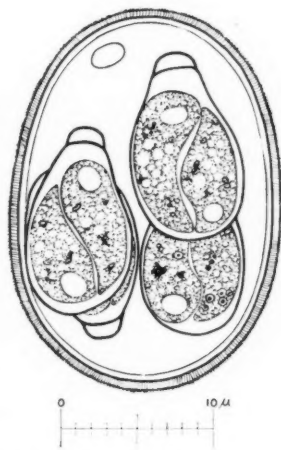


Fig. 2.—*Eimeria brinkmanni* n. sp. sporulated oocyst $\times 4000$.

manni n. sp. in honor of August Brinkmann, who first reported coccidia from *Lagopus mutus*.

Eimeria fanthami n. sp.

Fig. 3

This species was found in one of six ptarmigans (*Lagopus mutus rupestris*) from the Perry River Region of the Canadian Arctic. Five oocysts measured 18.0-20.1 x 27.0-29.2 microns, with a mean of 18.8 x 28.3 microns. Their length-width ratio ranged from 1.4 to 1.6, with a mean of 1.52. They were ellipsoidal in shape. No micropyle was present. The sporulated oocysts contained four sporocysts and one to three polar refractile granules. No oocyst residual body was present. The oocyst wall was composed of two layers, both of about the same thickness. The outer layer was smooth and slightly lighter than the inner layer, but the whole wall was practically colorless. The sporocysts were lemon-shaped, with a Stieda body at the small end. Each contained two sporozoites lying side by side with the large end of one next to the small end of the other. No sporocyst residual body was present. I am naming this species *Eimeria fanthami* n. sp. in honor of H. B. Fantham, who first reported coccidia from the genus *Lagopus*.

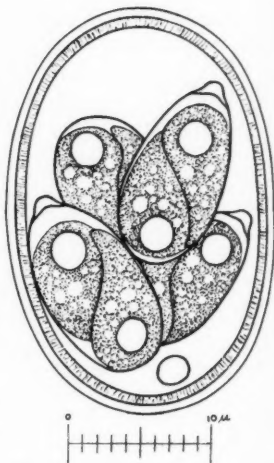


Fig. 3.—*Eimeria fanthami* n. sp. sporulated oocyst $\times 4000$.

SUMMARY

Coccidia were found in 6 of 49 wild birds of 21 species collected in the Perry River region on the Arctic Ocean in the Canadian Northwest Territory. *Eimeria brantae* n. sp. was found in the lesser Canada goose, *Branta canadensis parvipes*, *Eimeria* (?) or *Tyzzeria* (?) sp. in the old squaw duck, *Clangula hyemalis*, and the blue goose, *Chen caerulescens*, *Eimeria* (?) sp. from the ruddy turnstone, *Arenaria interpres morinella*, and *Eimeria brinkmanni* n. sp. and *E. fanthami* n. sp. from the rock ptarmigan, *Lagopus mutus rupestris*. The principal morphological characteristics and results of cross-infection experiments of *Cryptosporidium*, *Eimeria*, *Isospora* and *Wenyonella* from the avian orders Galliformes, Anseriformes and Charadriiformes are reviewed. *Eimeria dendrocopi* nom. nov. and *E. nonbrumpti* nom. nov. are assigned to forms previously described under the names *E. lyruri* and *E. brumpti*, respectively, from the woodpecker, *Dendrocopos* (= *Dryobates*) *major*.

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TABLE I.—Coccidia reported from order Anseriformes

| SPECIES AND HOSTS | Dimensions of oocysts (microns) | Length-width Ratio | Oocyst Shape and Color | Oocyst Micropyle | Oocyst Refr. Granule | Oocyst Residual Body | Sporocyst Residual Body | Reference |
|---|---------------------------------------|--------------------|---|---|----------------------|----------------------|-------------------------|--|
| <i>Eimeria anseris</i> Kötlan, 1932 emend. Kötlan, 1933 <i>Anser anser</i> (domestic goose) | 13-18 x 16-23 | | pyriform; colorless | + | + | + | small | Kötlan, 1933 |
| <i>Eimeria bucephalae</i> Christiansen and Madsen, 1948 <i>Bucephala clangula</i> (goldeneye duck) | 13-20 x 25-39 M. 16 x 30 M. 2.0 | 1.5-2.5; | ovoid, ellipsoid, or with one side indented; light brown, finely sculptured | + | + | — | + | Christiansen and Madsen, 1948 |
| <i>Eimeria magnalabiae</i> Levine, 1951 <i>Branta canadensis minor</i> (Canada goose) | 15-17 x 22-24 M. 16 x 22 | 1.3-1.5; M. 1.4 | sl. ovoid; wall heavy, pitted, brownish-yellow | + | — | — | + | Levine, 1951 |
| <i>Eimeria vocans</i> Kötlan, 1933 <i>Anser anser</i> (domestic goose) | 17-24 x 25-33 | | ovoid or ellipsoid; flat at micropyle end; outer wall thick, brownish | with thick hanging lips large; no polar cap + | — | — | + | Kötlan, 1933 |
| <i>Eimeria parvula</i> Kötlan, 1933 <i>Anser anser</i> (domestic goose) | 10-14 x 10-15 | | round or ellipsoid; colorless; sporont almost fills cyst | — | — | — | — | Kötlan, 1933 |
| <i>Eimeria truncata</i> (Railliet and Lucet, 1891) <i>Anser anser</i> (domestic goose) <i>Anser anser</i> (= <i>citreus</i>) (graylag goose) | 13-18 x 18-24 | | ovoid; with small end, narrow and truncate; fragile oocyst wall | + | + | + | + | Kötlan, 1933 |
| <i>Anas boschas</i> (domestic duck) <i>Branta canadensis canadensis</i> (Canada goose) <i>Somateria mollissima</i> (common eider) (?) | | | | | | | | Christiansen and Madsen, 1948 Pavlov, 1942 Cricher, 1950 Christiansen, 1946 |
| <i>Eimeria brantiae</i> n. sp. <i>Branta canadensis parvipes</i> (lesser Canada goose) | 8.13 x 11.25 18 x 24 | 1.3 | ovoid, elongate ovoid; or spherical wall | + | — | — | — | present paper |

| | 8.13 x 11.25 | avid, elongate ovoid; no apparent wall | + | + | present paper |
|---|-----------------------------|--|---|---|--|
| <i>Eimeria bruniae</i> n. sp. <i>Branta canadensis parvipap</i> (lesser Canada goose) | 18 x 24 | 1.3 | — | — | present paper |
| <i>Eimeria</i> or <i>Tyzzeria</i> sp. <i>Clangula hyemalis</i> (old squaw duck) <i>Chen caerulescens</i> (blue goose) | 9.12 x 11-16 | 1.2 | — | + | present paper |
| <i>Tyzzeria alleni</i> Chakravarty and Basu, 1946 <i>Cheniscus</i> (= <i>Nettapus</i>) <i>coro-</i> <i>mandelanus</i> (cotton teal) | 10-12 x 14-17 | oval; unsporulated oocyst completely filled by zygote | — | + | Chakravarty & Basu, 1946 |
| <i>Tyzzeria anseris</i> Nieschulz, 1947 <i>Anser anser</i> (domestic goose) | 10-12 x 12-16 M. 12 x 14 | ellipsoidal; wall thick, colorless | — | + | Nieschulz, 1947 |
| <i>Tyzzeria pernicioza</i> Allen, 1936 <i>Anas boschas</i> (Pekin domestic duck) | 9.11 x 10-13 | ellipsoidal; wall thick; unsporulated oocyst completely filled by zygote | — | + | Allen, 1936 |
| <i>Tyzzeria</i> sp. <i>Anas rubripes</i> (black duck) <i>Anser anser</i> (domestic goose) <i>Branta canadensis</i> (Canada goose) | 10-12 x 12-15 | elliptical | — | + | Farr, 1952 Farr & Wehr, 1952 |
| <i>Branta canadensis interior</i> (Canada goose) <i>Chen hyperborea atlantica</i> (greater snow goose) | 9.12 x 10-15 M. 11 x 13 | 1.0-1.4; M. 1.2 ellipsoidal; wall color- less; unsporulated oocyst almost filled by zygote | — | + | Farr, 1952 Levine, 1952 Farr, 1952 |

* Christiansen (1948) found coccidian oocysts in severe kidney lesions in this duck. He gave photomicrographs of unsporulated oocysts which resembled those of *E. truncata*, but did not describe them. He considered them to be presumably a new species, but until further information becomes available I consider it better to list this form under *E. truncata*.

** Three duck species have been domesticated. The Pekin duck is *Anas boschas*, the Indian runner is *Anas platyrhynchos*, and the Muscovy duck is *Carina moschata*. This is presumably *Anas boschas*.

(See also Families Phasianidae and Malesonidae)
Bonasia umbellus (cuffed grouse)
Pedioetes phasianellus campestris (sharp-tailed grouse)

17.20 x 18.23

sm. int. Boughdon, 1937

| <i>Eimeria lagopodis</i> Galli: Valerio, 1929 | | 15 x 24 | 1.6 | cylindrical, 1 end slightly flattened | + scarcely visible | Galli: Valerio, 1929 |
|--|--|--|--|--|--------------------|---------------------------|
| <i>Lagopus mutus</i> (ptarmigan) | | | | | | |
| <i>Eimeria lynxi</i> Galli: Valerio, 1927 | | 15 x 24.27 | | elongated cylindrical | + sl. visible | Galli: Valerio, 1927 |
| <i>Lynx tetrax</i> (black grouse) | | 12.20 x 22.37 M 15 x 30 | 1.2-2.5; M 2.0 | cylindrical, colorless | — | Yakimoff & Gousseff, 1936 |
| <i>Tetrao urogallus</i> (capercaillie) | | 15-18 x 22.34 M 16 x 28 13-21 x 22.35 M 17 x 29 | 1.3-2.1; M 1.8 1.3-2.3; M 1.7 | cylindrical, yellowish | — | Galli: Valerio, 1932 |
| <i>Dendrocyopos</i> (= <i>Dryobates</i>) major (woodpecker) | | | | cylindrical, sometimes yellowish | — | Yakimoff & Gousseff, 1936 |
| <i>Eimeria nadsoni</i> Yakimoff & Gousseff, 1936 | | Spherical 20-26; M 22 | Spherical 1.0 | spherical or subspherical | — | Yakimoff & Gousseff, 1936 |
| <i>Lynx tetrax</i> (black grouse) | | Subspherical 17-24 x 21-29 M 21 x 25 | Subspherical 1.1-1.3; M 1.2 | | — | |
| <i>Eimeria procera</i> Haase, 1939 | | 17 x 30 | 1.8 | ellipsoid with straight sides; wall uneven; dirty greenish | — | Haase, 1939 |
| (See also Family Phasianidae) | | | | | | |
| <i>Tetrao urogallus</i> (capercaillie) | | | | | | |
| <i>Eimeria tetrax</i> Haase, 1939 | | 15 x 31 | 2.0-2.1 | long ellipsoid with straight sides; wall smooth | +(?) | Haase, 1939 |
| <i>Lynx tetrax</i> (black grouse) | | | | | | |
| <i>Eimeria ventriosita</i> Haase, 1939 | | 22 x 32 | 1.5 | ellipsoid | + small | Haase, 1939 |
| <i>Tetrao urogallus</i> (capercaillie) | | | | | | |
| <i>Eimeria yakievi</i> (Yakimoff and Gousseff, 1936) | | | | | | |
| Hardcastle, 1943 | | | | | | |
| <i>Tetrao urogallus</i> (capercaillie) | | 20 diam. | 1.0 | spherical | — | Yakimoff & Gousseff, 1936 |
| <i>Dendrocyopos</i> (= <i>Dryobates</i>) major (woodpecker) | | 20.22 x 22.26 | 1.1-1.2 | spherical to subspherical; yellowish | — | |

TABLE II.—(continued.)

[illegible]

TABLE II.—(continued.)

| SPECIES AND HOSTS | Dimensions of Oocysts (microns) | Length-width Ratio | Oocyst Shape and Color | Oocyst Micropyle | Oocyst Refr. Granule | Oocyst Residual Body | Sporocyst Residual Body | Region of Intestine | Reference |
|---|---|--------------------|--------------------------|------------------|----------------------|----------------------|-------------------------|----------------------|--|
| <i>Eimeria hagani</i> Levine, 1938 <i>Gallus gallus</i> (chicken) | 14-19 x 16-21 M 18 x 19 | 1.1 | broad, ovoid | — | + | — | — | ant. small intes. | P. P. Levine, 1938 |
| <i>Eimeria kofoidi</i> Yakimoff and Matkashwili, 1936 * <i>Perdix perdix</i> (grey partridge) and/or * <i>Alectoris</i> (= <i>Caccabis</i>) <i>gareca chukar</i> (stone partridge) | 14-20 x 16-25 M 18 x 20 | 1.0-1.5 M 1.2 | ovoid (occas. spherical) | — | + | — | + | — | Yakimoff and Matkashwili 1936 |
| <i>Eimeria lungeromi</i> Yakimoff and Matkashwili, 1937 <i>Phasianus colchicus chryamelas</i> (ring-necked pheasant) <i>Phasianus colchicus gordius</i> (ring-necked pheasant) <i>Phasianus colchicus colchicus</i> (ring-necked pheasant) | 16-20 x 30-26 M 18 x 32 | 1.5-2.1 M 1.8 | ovoid or elongate ovoid | — | — | — | + | — | Yakimoff and Matkashwili, 1937 Yakimoff and Maculskij, 1940 |
| <i>Eimeria maxima</i> Tyzzer, 1929 <i>Gallus gallus</i> (chicken) <i>Gallus gallus</i> (chicken) | 16-30 x 21-42 M 23 x 29 20-28 x 26-36 M 23 x 30 | 1.3 1.3 | ovoid, yellowish | — | + | — | — | mid and post. intes. | Tyzzer, 1929 Johnson, 1938 |
| <i>Eimeria megalotomata</i> Ormsbee, 1939 <i>Phasianus colchicus</i> (ring-necked pheasant) | 16-22 x 21-29 M 19 x 24 | 1.3 | ovoid; light yellowish | + | + | — | — | — | Ormsbee, 1939 |
| <i>Eimeria mitis</i> Tyzzer, 1929 (See also Subfamily Odonophorinae) <i>Gallus gallus</i> (chicken) <i>Gallus gallus</i> (chicken) <i>Eimeria necatrix</i> Johnson, 1930 <i>Gallus gallus</i> (chicken) | 13-17 x 14-20 M 15 x 16 13-16 x 13-18 11-18 x 13-23 M 14 x 17 | 1.1 1.1 | subspherical | — | + | — | — | ant. small intes. | Tyzzer, 1929 Tyzzer, 1929 Tyzzer, 1929 Jones, 1932 |

| | | | | | | | | |
|---|---|--|---|---|---|-------------------------------------|--|---|
| <i>Eimeria mitis</i> Tyzzer, 1929 (See also Subfamily Odontophorinae) <i>Gallus gallus</i> (chicken) | 13-17 x 14-20 M 15 x 16 12-16 x 13-18 1.1 | sub spherical | — | + | — | — | ant. small intest. | Tyzzer, 1929 |
| <i>Eimeria necatrix</i> Johnson, 1930 <i>Gallus gallus</i> (chicken) | 11-18 x 13-23 M 14 x 17 1.2 | oblong ovoid | — | + | — | — | Schizonts in small intes.; oocysts in cecum | Tyzzer, Theiler and Jones, 1932 |
| <i>Eimeria pacifica</i> Ormsbee, 1939 <i>Phasianus colchicus</i> (ring-necked pheasant) | 14-20 x 17-26 M 18 x 22 1.2 | ovoid; light yellowish | — | + | ± | — | upper intes. and cecum | Ormsbee, 1939 |
| <i>Eimeria phasiani</i> Tyzzer, 1929 <i>Phasianus colchicus</i> (ring-necked pheasant) | 13-18 x 20-26 M 16 x 23 1.4 | ellipsoid | — | + | — | — | cecum | Tyzzer, 1929 |
| <i>Phasianus colchicus</i> (ring-necked pheasant) | 15-19 x 21-27 M 17 x 25 1.4 | ellipsoid; light yellowish brown | — | + | ± | 1 or 2 small dark granules | — | Ormsbee, 1939 |
| <i>Phasianus colchicus colchicus</i> (ring-necked pheasant) | 16 x 23 1.4 | ellipsoid | — | + | — | — | cecum | Haase, 1939 |
| <i>Phasianus colchicus torquatus</i> (ring-necked pheasant) | | | | | | | | |
| <i>Eimeria praecox</i> Johnson, 1930 <i>Gallus gallus</i> (chicken) | 16-20 x 20-25 19-22 x 22-25 M 21 x 24 1.2 1.1 | ovoid | — | + | — | (lateral) | ant. small intest. | Tyzzer, Theiler and Jones, 1932 Johnson, 1938 |
| <i>Eimeria procera</i> Haase, 1939 (See also Family Tetraonidae) <i>Perdix perdix</i> (grey partridge) | 17 x 30 1.8 | ellipsoid with straight sides; wall uneven; dirty greenish | — | + | — | — | — | Haase, 1939 |
| <i>Eimeria tenella</i> (Railliet and Lucet, 1891) (See also Subfamily Odontophorinae and Family Meleagridae) | | | | | | | | |

TABLE II.—(continued.)

| SPECIES AND HOSTS | Dimensions of Oocysts (microns) | Length-width Ratio | Oocyst Shape and Color | Oocyst Microtype | Oocyst Refr. Granule | Oocyst Residual Body | Sporocyst Residual Body | Region of Intestine | Reference |
|--|---------------------------------|--------------------|--------------------------------|-------------------|----------------------|----------------------|-------------------------|---------------------|-----------------------|
| <i>Gallus gallus</i> (chicken) | 16-23 x 20-36 M. 19 x 23 | 1.2 | broad ovoid | — | + | — | — | cecum | Tyzzer, 1929 |
| <i>Perdix perdix</i> (grey partridge) <i>Phasianus colchicus</i> (ring-necked pheasant) <i>Phasianus colchicus torquatus</i> (ring-necked pheasant) <i>Emeria</i> sp. Ornahee, 1939 | 15-19 x 20-25 18 x 24 | 1.3 | | | | | | | Johnson, 1938 |
| | 18 x 24 | usually 1.3-1.4 | ovoid | — | — | — | — | cecum | Haase, 1939 |
| | 15 x 18 | 1.2 | ovoid; yellowish brown | — | + | — | — | | Ormsbee, 1939 |
| | 20-28 | 1.0 | almost spherical | | | | | | Pavlov, 1942 |
| <i>Isopora</i> sp. Pavlov, 1942 | | | | | | | | | |
| <i>Chrysolophus pictus</i> (golden pheasant) | | | | | | | | | |
| <i>Cryptosporidium parvum</i> Tyzzer, 1912 | | | | | | | | | |
| <i>Gallus gallus</i> (chicken) | 3-4 x 3-5 | | ovoid or spherical | | | | | | Tyzzer, 1929 |
| <i>Wenyonella bahli</i> Misra, 1944 | | | | | | | | | |
| <i>Coturnix coturnix</i> (= <i>communis</i>) (grey quail) | 15-16 x 16-18 | | subspherical, ellipsoid, ovoid | — | — | — | — | sm. intes. | Misra, 1944 |
| <i>Wenyonella gallinae</i> Ray, 1945 | | | | | | | | | |
| <i>Gallus gallus</i> (chicken) | 20-23 x 30-34 | | ovoid; wall punctate and rough | + | + | — | + | terminal intes. | Ray, 1945 |
| COCIDIA OF HOST FAMILY | | | | | | | | | |
| MELEAGRIDAE | | | | | | | | | |
| <i>Eimeria acervulina</i> Tyzzer, 1929 | | | | | | | | | Henry, 1931 |
| (See also Family Phasianidae) | | | | | | | | | |
| <i>Meleagris gallopavo</i> (turkey) | | | | | | | | | Moore and Brown, 1951 |
| <i>Eimeria adenocider</i> Moore and Brown, 1951 | 13-21 x 19-31 M. 17 x 26 | 1.54 | ellipsoidal | sometimes present | + | — | — | lower ileum, caecum | Moore and Brown, 1952 |
| <i>Meleagris gallopavo</i> (turkey) | | | | | | | | | |
| (See also Family Phasianidae) | | | | | | | | | |
| <i>Meleagris gallopavo</i> (turkey) | 18-24 x 22-31 M. 21 x 26 | 1.2 | broad ovoid; single wall | — | — | — | — | duodenum | Hawkins, 1952 |

| | 13.21 x 19.31 M. 17 x 26 | 1.54 | ellipsoidal | sometimes present | + | lower ileum occurs, Brown, 1952 | Henry, 1931 Moore and Brown, 1952 |
|---|-----------------------------|------|------------------------------|----------------------|---|--|--|
| <i>Eimeria acervulina</i> Tyzzer, 1929 (See also Family Phasianidae) <i>Meleagris gallopavo</i> (turkey) Brown, 1951 (Family Phasianidae) <i>Meleagris gallopavo</i> (turkey) Brown, 1951 (Family Phasianidae) | 18.24 x 22.31 M. 21 x 26 | 1.2 | broad ovoid; angle wall | — | — | duodenum | Hawkins, 1952 |
| <i>Eimeria gallopavonis</i> Hawkins, 1952 <i>Meleagris gallopavo</i> (turkey) | 15.19 x 17.21 M. 17 x 27 | 1.5 | ellipsoidal; double wall | — | + | ileum rectum | Hawkins, 1952 |
| <i>Eimeria innocua</i> Moore and Brown, 1952 <i>Meleagris gallopavo</i> (turkey) | 17.25 x 19.26 M. 21 x 22 | 1.07 | subspherical | — | — | sm. intes. | Moore and Brown, 1952; Moore, 1952 |
| <i>Eimeria meleagridis</i> Tyzzer, 1927 <i>Meleagris gallopavo</i> (turkey) | 15.21 x 20.31 M. 18 x 24 | 1.3 | ellipsoidal; double wall | — | + | cecum | Hawkins, 1952 |
| <i>Eimeria meleagridis</i> Tyzzer, 1929 <i>Meleagris gallopavo</i> (turkey) | 13.22 x 16.27 M. 16 x 19 | 1.2 | subspherical; double wall | — | + | jejunum | Hawkins, 1952 |
| <i>Eimeria tenella</i> (Railliet and Lucet, 1891) (See also Family Phasianidae) <i>Meleagris gallopavo</i> (turkey) | | | | | | | Henry, 1931 |

* Described from feces in a cage which contained birds of both species. The authors thought that both species were infected.

This table includes only the valid species described from the chicken. In addition to the species listed herein, the following species described from the chicken should be mentioned:

- E. avium* auct.—synonym of *E. tenella*.
- E. beachi* Yakimoff and Rastegaieff, 1931—doubtful validity.
- E. brachyi* Géard, 1913—synonym of *E. tenella*.
- Eimeria* (sic) *commodum* Shaw, 1935—nomen nudum.
- E. dubia* Railliet, 1893—description unrecognizable.
- E. globosa* (Labbe, 1893)—synonym of *E. tenella*.
- E. johnsoni* Yakimoff and Rastegaieff, 1931—doubtful validity.
- E. tyzzeri* Yakimoff and Rastegaieff, 1931—doubtful validity.

TABLE III.—Summary of cross-infection experiments with *Eimeria* in Galliformes

| Eimeria Species | Donor Host | Receptor Host | Result | Reference |
|---------------------|---------------------|---------------------|--------|----------------------------------|
| <i>acervulina</i> | chicken | pheasant | — | Tyzzer, 1929 |
| | chicken | turkey | — | Tyzzer, 1929; Steward, 1947 |
| | chicken | bobwhite quail | — | Tyzzer, 1929; Patterson, 1933 |
| | chicken | chicken | — | Venard, 1933 |
| "acervulina" | bobwhite quail | chicken | — | Venard, 1933 |
| "acervulina" | Calif. valley quail | chicken | + | Henry, 1931 |
| "acervulina" | mountain quail | chicken | + | Henry, 1931 |
| "acervulina" | turkey | chicken | + | Henry, 1931 |
| <i>adenocides</i> | turkey | chicken | — | Moore and Brown, 1951 |
| | turkey | guinea fowl | — | Moore and Brown, 1951 |
| | turkey | pheasant | — | Moore and Brown, 1951 |
| | turkey | quail | — | Moore and Brown, 1951 |
| <i>angusta</i> | sage hen | chicken | — | Simon, 1939; Honess, 1942 |
| | | | | |
| <i>centrocerci</i> | sage hen | chicken | — | Simon, 1939; Honess, 1942 |
| | | | | |
| <i>dispersa</i> | bobwhite quail | chicken | + | Tyzzer, 1929 |
| | bobwhite quail | chicken | — | Venard, 1933; Patterson, 1933 |
| | bobwhite quail | pheasant | + | (?) Tyzzer, 1929 |
| | bobwhite quail | turkey | + | Tyzzer, 1929 |
| | pheasant | bobwhite quail | + | Tyzzer, 1929 |
| | turkey | bobwhite quail | + | Hawkins, 1952 |
| | turkey | Hungarian partridge | + | Hawkins, 1952 |
| | turkey | pheasant | + | Hawkins, 1952 |
| | turkey | chicken | ? | Hawkins, 1952 |
| | | | | |
| <i>gallopavonis</i> | turkey | pheasant | — | Hawkins, 1952 |
| | turkey | bobwhite quail | — | Hawkins, 1952 |
| | turkey | Hungarian partridge | + | Hawkins, 1952 |
| <i>innocua</i> | turkey | chicken | — | Moore and Brown, 1952 |
| | turkey | guinea fowl | — | Moore and Brown, 1952 |
| | turkey | pheasant | — | Moore and Brown, 1952 |
| | turkey | quail | — | Moore and Brown, 1952 |

TABLE III.—(continued)

| Eimeria Species | Donor Host | Receptor Host | Result | Reference |
|-----------------------|---------------------|---------------------|--------|----------------------------------|
| <i>maxima</i> | chicken | bobwhite quail | — | Patterson, 1933 |
| <i>meleagridis</i> | turkey | chicken | — | Tyzzer, 1929 |
| | turkey | chicken | + | Steward, 1947 |
| | turkey | pheasant | — | Tyzzer, 1929 |
| | turkey | bobwhite quail | — | Tyzzer, 1929 |
| | turkey | bobwhite quail | — | Hawkins, 1952 |
| | turkey | Hungarian partridge | — | Hawkins, 1952 |
| <i>meleagrimitis</i> | turkey | bobwhite quail | — | Hawkins, 1952 |
| | turkey | Hungarian partridge | — | Hawkins, 1952 |
| <i>mitis</i> | chicken | bobwhite quail | — | Patterson, 1933 |
| " <i>mitis</i> " | Calif. valley quail | chicken | + | Henry, 1931 |
| " <i>mitis</i> " | mountain quail | chicken | + | Henry, 1931 |
| <i>phasiani</i> | pheasant | chicken | — | Tyzzer, 1929; Patterson, 1933 |
| | pheasant | turkey | — | Tyzzer, 1929 |
| | pheasant | bobwhite quail | — | Tyzzer, 1929 |
| <i>tenella</i> | chicken | turkey | — | Patterson, 1933 |
| | chicken | pheasant | — | Patterson, 1933 |
| | chicken | bobwhite quail | — | Patterson, 1933 |
| " <i>tenella</i> " | bobwhite quail | chicken | + | Venard, 1933 |
| " <i>tenella</i> " | turkey | chicken | + | Henry, 1931 |
| mixed chicken species | chicken | turkey | — | Johnson, 1923 |
| mixed quail species | Calif. valley quail | chicken | — | Herman, 1949 |

Studies on Monogenetic Trematodes. XIV. Dactylogyridae from Wisconsin Fishes

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The 17 species of Monogenea treated herein were collected from Wisconsin waters in 1947 by Dr. R. V. Bangham of Wooster College, Wooster, Ohio, to whom the authors express a debt of gratitude.

The host material was first frozen and then preserved in formalin. After arrival at our laboratory, the gills were placed in small vials about two-thirds full of tap water and shaken vigorously in order to free the parasites from the branchial tissue. This material was then transferred to Syracuse watch glasses and diluted and decanted until clear enough for reliable examination with a dissectoscope. Individual specimens were collected with a capillary pipette equipped with a rubber bulb and transferred to clear water for removal of excess mucus. Each of the permanent mounts was made by selecting a specimen microscopically with a capillary pipette and transferring it to a drop of solidified glycerin-gelatin medium on a clean glass slide. A cover glass which was placed thereon settled in place as the medium was melted with gentle heat. The slide was cooled, the medium congealed, and a permanent mount was thus produced.

Measurements were made with a compound microscope and a calibrated ocular micrometer for (1) body length, (2) greatest body width, (3) length of haptor bars, (4) length and (5) width of anchors, (6) length of cirrus, (7) length of accessory piece, (8) length of hooks, and (9) transverse diameter of pharynx. Curved structures were measured as a straight line extending between the two most distant parts of such structures. Measurements of anchor lengths, for example, extend from the tip of the *superficial* root to the most distant point on the curved portion in the region of junction of the shaft and point. The width of the anchors is the greatest width of an anchor base. A mean measurement was calculated (in the case of two or more specimens) and consists of an average derived from the measurements of the same structure in different individuals. All measurements, except those for body length, and body width which were made with a low-power objective (16 mm), were done with an oil-immersion objective.

Available specimens up to a maximum of 27, were used in the treatment of a given species. One species of Tetraonchinae (*Urocleidus chrysops* from the white bass, *Lepibema chrysops*) and seven Dactylogyridae (*Dactylogyrus attenuatus*, *D. claviformis*, and *D. lineatus* (all) from the northern creek chub, *Semotilus a. atromaculatus*; *D. distinctus* from the northern mimic shiner, *Notropis v. volucellus*; *D. dubius*, *D. pyriformis*, and *D. vannus* from the northern common shiner, *Notropis cornutus frontalis*) are new. The host distribution of the remaining nine species is as follows: *Cleidodiscus*

brachus and *Dactylogyrus microphallus* from the northern creek chub, *Semotilus a. atromaculatus*; *C. floridanus* from the channel catfishes, *Ictalurus l. lacustris* and *I. lacustris punctatus*; *C. pricei* from the northern channel cat. *I. l. lacustris*; *Urocleidus mimus* from the white bass, *Lepibema chrysops*; *Murraytrema copulata* from the common sucker, *Catostomus c. commersonnii* and the northern red horse, *Moxostoma aureolum*; *Dactylogyrus bulbosus* and *D. cornutus* from the northern common shiner, *Notropis cornutus frontalis*; and *D. extensus* from the carp, *Cyprinus carpio*. Comparative information is from original descriptions and is indicated by quotation marks.

CLEIDODISCUS BRACHUS Mueller, 1938

Figs. 1-3

Host and locality.—*Semotilus a. atromaculatus*, Fish Creek, Bayfield Co. and Pine River, Clarence Co., Wis.

Previously reported hosts and locality.—*Semotilus atromaculatus* and *Margariscus margarita*, French Creek, near Panama, N. Y. (Mueller, 1938).

Specimens studied.—Five.

Comparative description.—Moderately short, stocky forms provided with a moderately thick cuticle; length 0.554 mm (0.468-0.756 mm) "as much as 1.2 mm long," greatest width 0.180 mm (0.144-0.198 mm) "about 0.18 mm wide." Eye spots four, members of the posterior pair larger and usually farther apart than those of the anterior pair "anterior slightly closer together than posterior." Cephalic lobes inconspicuous; pharynx subcircular in outline (dorsal view) and 0.053 mm (0.041-0.054 mm) in transverse diameter. Peduncle short and broad; haptor irregularly ovoid in outline (dorsal view) and narrower than body, "wedge shaped." Anchors dissimilar in size, each composed of 1) a base with well-differentiated roots, 2) a shaft which unites with 3) a solid point. Bases of ventral anchors cavernous and characterized by the formation of a spur-like structure at the junction of the proximally hollow shaft (fig. 1). Dorsal anchors each with a relatively narrow base, solid shaft, and point (fig. 2). Anchor wings present near junction of base and shaft. Superficial roots of bases of both pairs of anchors longer than deep roots. Ventral anchor length 0.047 mm (0.045-0.048) "greatest anchor length 0.050 mm," greatest width of base 0.027 mm (0.021-0.031 mm); dorsal anchor length 0.045 mm (0.043-0.046 mm) "greatest length of dorsal anchor 0.046 mm," greatest width of base 0.015 mm (0.014-0.016 mm). Bars as figured in original description, (Mueller, 1938, Pl. 2, figs. 4-6), except that a well-differentiated cavity is infrequently present in the ventral bar. Ventral bar length 0.039 mm (0.036-0.042 mm); dorsal bar length 0.029 mm. Hooks fourteen in number, morphologically similar, subequal in length, and normal in arrangement (Mizelle, 1938). Hook bases short, shafts slender, opposable piece of sickle-shaped termination blunt; posteriorly projecting structure not observed on hooks (fig. 3). Members of hook pair No. 5 (No. 7 of Mueller) present on the posterior margin of haptor between dorsal and ventral anchors "not observed." Hook lengths 0.016-0.022 mm "about equal in size, 0.023 mm long." Ovary irregularly ovoid in outline and situated anterior to the testis which is approximately the same size. Vitellaria heavily developed and confluent in midline of body so as to render observation of internal structures extremely difficult. Vagina not observed. Copulatory complex as originally described (Mueller, 1938, Pl. 2, figs. 9, 25). Cirrus length 0.028 mm (0.027-0.029 mm); accessory piece length 0.022 mm. Seminal vesicle well developed, prostates not observed.

CLEIDODISCUS FLORIDANUS Mueller, 1936

Fig. 4

Hosts and localities.—*Ictalurus l. lacustris*, *Ictalurus lacustris punctatus*, St. Croix River, Burnett Co. and Upper Lake Pepin, Mississippi River, Wis.

Previously reported hosts and localities.—*Ictalurus furcatus*, Reelfoot Lake, Ridgely,

Tenn. (Mizelle and Cronin, 1943). *Ictalurus lacustris punctatus*, Myakka River, Fla. and Lake Okechobee, Fla. (Mueller, 1936a) and Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Ameiurus melas*, Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Pilodictis olivaris*, Mississippi River (Mueller, 1937).

Synonym.—*Cleidodiscus mirabilis* Mueller, 1937 (in part).

Specimens studied.—Twenty-seven.

Comparative description.—Relatively large species provided with a thin, smooth cuticle; length 0.970 mm (0.792-1.224 mm) "in normal state of contraction about 0.7 mm long," greatest width 0.127 mm (0.090-0.162 mm) "0.14 mm wide." Eye spots four, posterior pair larger; distance between members of pairs of eye spots variable. Cephalic lobes prominent; pharynx subcircular to ovate in outline (dorsal view) and 0.040 mm (0.033-0.050 mm) in transverse diameter, "0.05 mm in diameter." Peduncle variable in width and length; haptor distinctly hexagonal in outline. Anchors similar morphologically and composed of 1) bases frequently without differentiated roots, 2) solid shafts, and 3) solid points. Anchors frequently possessing bifurcate bases and identical with those of "*C. mirabilis*." Ventral anchor length 0.064 mm (0.050-0.096 mm), greatest width of base 0.031 mm (0.021-0.046 mm); dorsal anchor length 0.058 mm (0.046-0.071 mm), greatest width of base 0.032 (0.025-0.042 mm). "Large hooks equal in size and similar in shape, 0.058 mm in greatest straight dimension, with flat, undivided roots." Ventral and dorsal bars with variations which duplicate those figured for *C. mirabilis* Mueller, 1937 (J. figs. 49, 50) and *C. floridanus* Mueller, 1936 (a) (Pl. 57, fig. 16). Ventral bar length 0.085 mm (0.058-0.100 mm); dorsal bar 0.077 mm (0.042-0.092 mm) in length; "ventral about 0.074 mm in greatest dimension, dorsal 0.078 mm." Hooks fourteen in number, normal in arrangement (Mizelle, 1938), and identical with those originally figured for *C. floridanus* (Mueller 1936a, Pl. 57). Hook lengths 0.015-0.018 mm "about 0.018 mm long." Copulatory complex well developed and composed of a basally articulate cirrus and accessory piece, cirrus as originally figured for *C. floridanus* Mueller, 1936 (a), Pl. 57, figs. 17, 18 and *C. mirabilis* Mueller, 1937, J., fig. 6. Accessory piece extremely variable (fig. 4; Mueller, 1936a, Pl. 57, figs. 17, 18; 1937, J., fig. 7; Mizelle and Cronin, 1943, Pl. 2, figs. 6-11). Cirrus length 0.088 mm (0.066-0.104 mm) "about 0.045 mm"; accessory piece length 0.081 mm (0.066-0.096 mm).

The observation of variations which include and far exceed descriptions and illustrations for *C. floridanus* and *C. mirabilis* confirm the intimations of Mizelle and Cronin (1943) that these two species were identical.

CLEIDODISCUS PRICEI Mueller, 1936

Host and locality.—*Ictalurus l. lacustris*, Upper Lake Pepin and Mississippi River, Wis.

Previously reported hosts and localities.—*Ictalurus furcatus*, Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Ictalurus lacustris punctatus*, Myakka River, Fla. and Lake Okechobee, Fla. (Mueller, 1936a) and Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Ameiurus melas*, Local Ponds and Streams near Stillwater, Okla. (Seamster, 1938), Baton Rouge, La. (Summers and Bennett, 1938), and Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Ameiurus natalis*, Myakka River, Fla. and Lake Okechobee, Fla. (Mueller, 1936a) and Reelfoot Lake, Ridgely, Tenn. (Mizelle and Cronin, 1943). *Ameiurus nebulosus*, Myakka River, Fla. and Lake Okechobee, Fla. (Mueller, 1936) and Oneida Lake, New York (Mueller, 1937).

Specimens studied.—Three.

Comparative description.—Moderately large forms provided with a thin, smooth cuticle; length 0.732 mm (0.684-0.792 mm) "length 0.62 mm," greatest width 0.083 mm (0.074-0.092 mm) "0.14 mm." Eye spots four, members of the posterior pair larger and closer together than those of the anterior pair. Cephalic lobes small; pharynx subcircular to ovate in outline (dorsal view) and 0.022 mm in transverse diameter, "0.04 mm in diameter." Peduncle of moderate size and narrower than body proper; haptor hexagonal in outline. Anchors morphologically variable, with well differentiated bases, solid recurved shafts and tips (Seamster, 1938, figs. 1-3, 6, 7; Mizelle and Cronin,

1943, Pl. 1, figs. 65-72). The anchors slightly resemble those of *C. floridanus* (Mueller, 1936a, fig. 16), except that the anchor shafts of *C. pricei* are more curved. Ventral anchor length 0.052 mm (0.049-0.053), width of base 0.025 mm; dorsal anchor length 0.055 mm (0.050-0.058 mm), width of base 0.027 mm "large hook, 0.048 mm." Bars dissimilar and variable. Ventral bar bent near midportion and with rounded ends, dorsal bar usually with an ornate anterior surface and somewhat variable (Seamster, 1938, figs. 1-3, 6, 7; Mizelle and Cronin, 1943, Pl. 1, fig. 74; Mizelle and Regensberger, 1945, Pl. 1, fig. 51, 52). Ventral bar length 0.048 mm (0.046-0.049 mm) "ventral bar 0.05 mm"; dorsal bar length 0.051 mm (0.049-0.054 mm) "dorsal bar 0.058 mm." Hooks fourteen in number, normal in arrangement (Mizelle, 1938), and as described by Mizelle and Regensberger (1945, Pl. 1, figs. 53-55). Ovary elliptical in outline, testis ovate and located posterior to the ovary. Vagina not observed. Vitellaria well developed with the bands confluent except in a section of the midbody. Seminal vesicle and prostates not observed. A highly chitinated, dumb-bell shaped structure, was observed near the midlength of the body in one of the specimens. Copulatory complex as previously described (Mueller, 1936a, Pl. 57, figs. 13-15). Cirrus length 0.027 mm, "about 0.037 mm"; no exact measurements were obtained for the accessory piece.

Uroleidus chrysops n. sp.

Figs. 5-17

Host and localities.—*Lepibema chrysops*, Upper Lake Pepin and Mississippi River, Wis.

Specimens studied.—Three.

Type specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Moderately small Tetraonchinae provided with a thin, transparent cuticle; length 0.609 mm (0.585-0.666 mm), greatest width 0.115 mm (0.099-0.141 mm). Eye spots four, members of the posterior pair larger and farther apart than those of the anterior pair. Cephalic lobes distinct; pharynx subcircular in outline (dorsal view) and 0.033 mm (0.030-0.036 mm) in transverse diameter. Peduncle of moderate size; haptor subhexagonal in outline. Anchors morphologically similar, each composed of 1) a base with well-differentiated roots, 2) a slender solid shaft, and 3) a solid point (figs. 12, 13). Anchor wings very weakly developed. Both ventral anchors with shaft conspicuously bent proximally in the direction of the anchor point with which it unites obtusely. This condition is present with reference to the dorsal anchors but to a lesser degree. Ventral anchor length 0.065 mm (0.062-0.069 mm), width of base 0.033 mm (0.029-0.037 mm); dorsal anchor length 0.059 mm (0.058-0.060 mm), width of base 0.025 mm. Ventral bar usually with an irregular posterior margin, often enlarged in midportion, and with the ends developed to enclose or partially enclose a space, figs. 7, 8). Ventral bar length 0.053 mm (0.049-0.056 mm); dorsal bar length 0.046 mm. Dorsal bar usually gently curved posteriorly in midportion and with enlarged ends (figs. 5, 6). Hooks fourteen in number and normal in arrangement (Mizelle, 1938). Base of hooks of pair No. 1 developed to the extent of almost obliterating the hook shaft (fig. 9). Posteriorly projecting structure on base of sickle-shaped termination of hook not observed. Remaining hooks (except pair No. 5) with bases developed less extensively so that a short but definite shaft is present (fig. 11). Hooks of pair No. 5 each with an elongate base of approximately the same length as the slender shaft (fig. 10). Hooks of pair numbers one and seven longest. Hooks of pair number five shortest. Hooks of remaining pairs of similar size. Hook lengths: pair No. 1, 0.035 mm (0.033-0.036 mm); No. 2, 0.026 mm (0.025-0.027 mm); No. 3, 0.026 mm (0.025-0.027 mm); No. 4, 0.027 mm; No. 5, 0.018 mm; No. 6, 0.028 mm; No. 7, 0.033 mm (0.031-0.036 mm). Gonads ovate in outline, testis more elongate and situated posterior to the ovary. Vitellaria distributed in two lateral bands which are narrower than usually observed in North American fresh-water Tetraonchinae. In one specimen the vitellarial band on one side was so weakly developed as to be almost non-existent. Vagina not observed with certainty. Copulatory complex well developed and consisting of a cirrus and accessory piece (figs. 14-17). Cirrus composed of a moderate-sized base and a relatively short, terminally bent shaft which possesses a cirral thread, length 0.040 mm. Accessory piece

not articulate basally with the cirrus and consisting of what is apparently a chitinated portion of the vestibule which, at times, presents a sleeve-like appearance (figs. 16, 17). Accessory piece length 0.028 mm (0.027-0.029 mm). Prostates and seminal vesicle well developed.

The closest relative of *U. chrysops*, from the standpoint of the copulatory complex, is *U. procax* Mizelle and Donahue, 1944 (Pl. 1, figs. 62-67). Whereas the haptoral armament of *U. procax* is similar to that of *U. ferox* Mueller, 1934; corresponding structures in *U. chrysops* differ radically from those of other described North American species. This difference is most conspicuous with reference to the ventral anchors (fig. 12). *U. chrysops* is the second species of Tetraonchinae to be described from *Lepibema chrysops*.

UROCLEIDUS MIMUS (Mueller, 1936)

Figs. 18-20

Host and locality.—*Lepibema chrysops*, Lake Pepin, Mississippi River, Wis.

Synonym.—*Onchocleidus mimus* Mueller, 1936.

Previously reported hosts and locality.—*Esox reticulatus* and *Lepibema chrysops*, London, O. (Mueller, 1936).

Specimens studied.—Fourteen.

Comparative description.—Relatively large forms provided with a thin, smooth cuticle; length 1.021 mm (0.756-1.188 mm), greatest width 0.145 mm (0.108-0.192 mm). Eye spots four, members of the posterior pair larger and farther apart than those of the anterior eye spots. Cephalic lobes conspicuous; pharynx circular in outline (dorsal view) and 0.059 mm (0.054-0.063 mm) in transverse diameter. Peduncle of moderate size; haptor irregularly pentagonal or hexagonal in outline. Anchors morphologically similar and composed of 1) bases with well-differentiated superficial and deep roots, 2) solid shafts, and 3) solid points. Ventral anchor length 0.037 mm (0.033-0.042 mm), greatest width of base 0.025 mm (0.021-0.029 mm); dorsal anchor length 0.038 mm (0.033-0.042 mm), greatest width of base 0.021 mm (0.017-0.025 mm). "Anchors with greatest dimension of 0.03 mm." Dorsal bar shorter than ventral and 0.030 mm (0.021-0.033 mm) in length; ventral bar length 0.039 mm (0.033-0.042 mm). Hooks fourteen in number, unequal in size, and normal in arrangement (Mizelle, 1938). The first pair of hooks is the smallest of the fourteen members. Each hook composed of an elongate-ovate base, a comparatively short shaft, a sickle-shaped termination (fig. 20) and not as figured originally (Mueller, 1936, Pl. 13, fig. 13). Hook lengths 0.022-0.035 mm. Ovary ovate and situated anterior to the elongate-ovate and smaller testis. Vagina not observed. Vitellaria well developed and distributed as two lateral bands which are confluent anteriorly near the pharynx and posteriorly near the proximal portion of the peduncle. Copulatory complex composed of 1) a narrow, thin walled cirrus, (fig. 18), traversed by a cirral thread and 2) an accessory piece which is not articulated to the cirrus (fig. 19). Cirrus length 0.045 mm (0.040-0.049 mm) "0.07 mm long"; accessory piece length 0.018 mm (0.015-0.020 mm). Seminal vesicle and prostates well developed.

This species was originally described (Mueller, 1936) and figured without an accessory piece. The presence of this structure supports the synonymy imposed on the old genus *Onchocleidus* Mueller, 1936 by Mizelle and Hughes, 1938.

MURRAYTREMA COPULATA Mueller, 1938

Figs. 21-28

Hosts and localities.—*Catostomus c. commersonnii* and *Moxostoma aureolum*, Silver Creek, Fond du Lac Co. and St. Croix River, Burnett Co., Wis.

Previously reported hosts and localities.—*Catostomus commersonnii*, *Hypentelium nigricans*, *Moxostoma anisurum*, *Moxostoma erythrurum*, Chautauqua Lake and French Creek, near Panama, N. Y. (Mueller, 1938).

Specimens studied.—Seven.

Comparative description.—Large forms provided with a comparatively thick, smooth cuticle; length 1.779 mm (1.224-2.700 mm) "1.5 to 3 mm," greatest width 0.319 mm (0.234-0.374 mm) "width from 0.25-0.50 mm." Eye spots four, members of the poste-

rior pair usually larger and farther apart than those of the anterior pair. Cephalic lobes absent; pharynx subcircular to ovate in outline (dorsal view) and 0.115 mm (0.100-0.142 mm) in transverse diameter. Peduncle narrow and elongate; haptor knob-like. Anchors morphologically similar and each composed of 1) a base with non-differentiated roots (usually), 2) a solid shaft, and 3) a solid point. Ventral anchors occasionally with slightly bifurcate, cavernous bases (fig. 22); dorsal anchor bases infrequently showing a tendency toward bifurcation (fig. 21). Ventral anchor length 0.075 mm (0.066-0.088 mm), greatest width of base 0.044 mm (0.033-0.050 mm); dorsal anchor length 0.075 mm (0.066-0.088 mm), greatest width of base 0.046 (0.038-0.054 mm) "ventral and dorsal anchors approximately equal in length, 0.074 mm" (Mueller, 1938, Pl. 1; figs. 7, 13). Characteristic of the genus is the presence of one ventral bar 0.062 mm (0.054-0.071 mm) in length, and two dorsal bars of approximately equal size but varying in different specimens and 0.069 mm (0.046-0.096 mm) in length. "Central bar (ventral) 0.06 mm long." Hooks fourteen in number, small and of equal size, and with arrangement typical of the genus. Each hook composed of a shaft (base incorporated), and a well developed sickle-shaped termination (fig. 23). Ovary irregularly elongate-ovate and partially covered by the dorso-posterior ovate testis. Ovary often situated in one side of the body. Vagina not observed. "Vagina opens in the ventral median area to the right of and slightly posterior to the cirrus." Vitellaria well developed, extending from the base of the pharynx to the anterior portion of the peduncle; vitellarial bands confluent except in region of gonads. Copulatory complex well developed, variable, and consisting of a basally articulate cirrus and accessory piece which are situated at the base of a fleshy process whose tip is lightly chitinated and possesses an orifice (figs. 24-28). Cirrus with large base and tubular shaft; cirrus length 0.042 mm (0.036-0.045 mm). Accessory piece length 0.037 mm (0.033-0.039 mm). Seminal vesicle and prostates not observed.

***Dactylogyrus attenuatus* n. sp.**

Figs. 29-39

Host and locality.—*Semotilus a. atromaculatus*, Fish Creek, Bayfield Co., Wis.

Specimens studied.—Three.

Type specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Moderately small dactylogyrids provided with a smooth, thin cuticle; length 0.269 mm (0.250-0.288 mm), greatest width 0.078 mm (0.072-0.090 mm). Eye spots four, members of the posterior pair usually slightly larger and farther apart than those of the anterior pair. Cephalic lobes conspicuous; anterior cephalic region cleft medially. Pharynx circular in outline (dorsal view) and 0.032 mm (0.029-0.033 mm) in transverse diameter. Peduncle short and broad; haptor hexagonal in outline. Anchor composed of 1) a base with well-differentiated superficial and deep roots, 2) a solid shaft, and 3) a solid point (fig. 29). Anchor length 0.041 mm (0.038-0.046 mm), greatest width of base 0.022 mm (0.020-0.026 mm). Dorsal bar usually with rounded ends (figs. 30, 31); length 0.032 mm (0.031-0.033 mm). Vestigial ventral bar length 0.024 mm (fig. 32). Hooks fourteen in number, approximately equal in size, and normal in arrangement (Mizelle, 1938). Each hook consists of 1) an inflated elongate-ovate base as long or longer than the 2) slender solid shaft, and 3) a sickle-shaped termination (figs. 37-39). Hook length 0.022 mm. Ovary ovate and situated anterior to the more elongate testis. Vitellaria well developed, bands confluent throughout their length and extend from the posterior border of the pharynx to the peduncle. Vagina not observed. Copulatory complex consisting of a cirrus and accessory piece (figs. 33-36). Cirrus relatively short and gently curved; length 0.027 mm (0.025-0.029 mm). Accessory piece irregularly shaped; length 0.017 mm (0.016-0.018 mm). Seminal vesicle and prostates not observed.

It is rather difficult to name the closest relative of *D. attenuatus*. The dorsal bar resembles that of *D. scutatus* Mueller, 1938, however, the copulatory complex, anchors and hooks differ markedly from those of this species. The morphology of the vestigial ventral bar and copulatory complex distinguish this form from all other described North American species.

DACTYLOGYRUS BULBUS Mueller, 1938

Figs. 40-46

Host and locality.—*Notropis cornutus frontalis*, Fish Creek, Bayfield Co., Wis.*Previously reported host and localities.*—*Notropis cornutus*, Chautauqua Lake, N. Y. (Mueller, 1938), and Proulx Lake in Algonquin Park, Ont., Can. (Mizelle and Donahue, 1944).*Specimens studied.*—Seven.

Comparative description.—Relatively small dactylogyrids provided with a moderately thick, transparent cuticle; length 0.374 mm (0.324-0.432 mm) "about 0.38 mm," greatest width 0.069 mm (0.054-0.072 mm) "0.2 mm." Four eye spots, approximately equal in size; distance between individual pairs, variable. Cephalic lobes conspicuous; anterior cephalic margin cleft medially. Pharynx subcircular in outline (dorsal view) and 0.027 mm (0.021-0.029 mm) in transverse diameter "0.026 mm in diameter." Peduncle short and moderately broad; haptor pentagonal or ovate in outline. Anchor composed of 1) a base with well-differentiated superficial and deep roots, 2) a solid shaft, and 3) a solid point (fig. 40 and Mueller, 1938, Pl. 3; fig. 26). Anchor length 0.031 mm (0.028-0.039 mm) "about 0.035 mm long," greatest width of base 0.020 mm (0.017-0.021 mm). Dorsal bar gently arched anteriorly and possessing round ends (fig. 41); length 0.025 mm (0.021-0.029 mm) "about 0.022 mm long." Vestigial ventral bar variable (figs. 42-44) and not as originally figured (Mueller, 1938, Pl. 3; fig. 25). Hooks fourteen in number, unequal in length, and normal in arrangement (Mizelle, 1938). Each hook consists of an elongate-ovate base about the length of its respective shaft, and a sickle-shaped termination (figs. 45, 46). Hook lengths 0.018-0.026 mm. Testis elongate-ovate and situated posterior to the ovate ovary which contains several large eggs. Vagina not observed with certainty. "Vagina present on the right ventral margin, but not conspicuous." Vitellaria well developed and distributed from the pharynx to the peduncle as two lateral bands which are confluent anteriorly and posteriorly. Copulatory complex as originally described (Mueller, 1938), except that the transverse process of the accessory piece is bent ventrally as described by Mizelle and Donahue, (1944; figs. 21-23). Cirrus length 0.038 mm (0.036-0.041 mm); accessory piece length 0.027 mm. (0.026-0.029 mm). Seminal vesicle and prostates well defined.

Dactylogyrus claviformis n. sp.

Figs. 47-52

Host and locality.—*Semotilus a. atromaculatus*, Fish Creek, Bayfield Co., Wis.*Specimens studied.*—Two.*Type specimens.*—Cotypes, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Relatively small species provided with a smooth, very thin cuticle; length 0.342 mm (0.324-0.360 mm), greatest width 0.087 mm (0.083-0.090 mm). Eye spots four, members of the posterior pair larger and farther apart than those of the anterior pair; accessory melanistic granules present in vicinity of eye spots. Cephalic lobes prominent; anterior cephalic region cleft medially. Pharynx ovate in outline (dorsal view) and 0.026 mm in transverse diameter; peduncle short and broad. Anchor composed of 1) a base with well-differentiated superficial and deep roots, 2) a solid shaft, and 3) a solid point. Anchor wing present near the distal end of the shaft (fig. 47). Anchor length 0.043 mm (0.040-0.047 mm), greatest width of base 0.020 mm. Vestigial ventral bar not observed. Dorsal bar slender with rounded ends and 0.031 mm (0.029-0.033 mm) in length (fig. 48). Hooks fourteen in number and normal in arrangement (Mizelle, 1938). Each hook is composed of an elongate-ovate base, a slender shaft, and a sickle-shaped termination (figs. 51, 52). Hook lengths 0.020-0.027 mm. Gonads situated near the body midlength and ovate in outline; ovary anterior to testis. Vitellaria highly developed, extending from base of pharynx to peduncle; vitellarial bands confluent throughout their extent. Vagina not observed with certainty. Copulatory complex well developed and consisting of a proximally articulate cirrus and accessory piece (figs. 49, 50). Cirrus composed of a relatively elongate, club-shaped base and an attenuated tubular shaft. Cirrus length 0.030 mm (0.029-0.031 mm). Accessory piece spiciform;

length 0.017 mm (0.016-0.018 mm). Prostates and seminal vesicle not observed with certainty.

It is difficult to name the nearest relative of *D. claviformis*. The hooks are similar to those of *D. vannus* n. sp., whereas the anchors resemble those of *D. microphallus* Mueller, 1938. The characteristic copulatory complex is not similar to any described *Dactylogyrus* species.

DACTYLOGYRUS CORNUTUS Mueller, 1938

Host and locality.—*Notropis cornutus frontalis*, Fish Creek, Bayfield Co., Wis.

Previously reported host and localities.—*Notropis cornutus*, Proulx Lake in Algonquin Park, Ont., Can. (Mizelle and Donahue, 1944), and Chautauqua Lake, N. Y. (Mueller, 1938).

Specimens studied.—Two.

Comparative description.—Relatively small forms provided with a very thin cuticle; length 0.504 mm "about 0.350 mm long," greatest width 0.092 mm (0.087-0.096 mm) "0.08 mm wide." Eye spots four, approximately equal in size and members of each pair about the same distance apart. Cephalic lobes well defined; pharynx ovate, dorso-ventrally elongate and 0.036 mm in transverse diameter, "0.026 mm in diameter." Peduncle short and narrow; haptor irregularly ovoid in outline. Each anchor composed of 1) a base with well-defined roots, 2) an evenly curved, solid shaft, and 3) a solid point. Anchor length 0.046 mm "about 0.039 mm long." Vestigial ventral bar not observed; dorsal bar 0.025 mm in length "about 0.030 mm long." Hooks fourteen in number, subequal in length, and normal in arrangement (Mizelle, 1938). Hook lengths 0.022-0.026 mm. Gonads not observed with certainty. Vagina not observed. "Vagina present on right in form of a simple vestibule without thickened walls" (Mueller, 1938). The cirrus is a long, slender tube which may be bent or straight (Mueller, 1938, Pl. 3, fig. 7; and Mizelle and Donahue 1944, Pl. 2, fig. 51). The small, solid accessory piece articulates with the base of the cirrus, and may be situated so as to appear as a highly chitinated portion of the cirrus base. Cirrus length 0.046 mm (0.045-0.047 mm); accessory piece length 0.017 mm (0.016-0.018 mm). Vitellaria weakly developed and uniformly distributed over body surface between pharynx and peduncle. Seminal vesicle well defined.

D. cornutus is readily identified by its characteristic copulatory complex.

Dactylogyrus distinctus n. sp.

Figs. 53-59

Host and locality.—*Notropis v. volucellus*, Trout Creek, Iowa Co., Wis.

Specimens studied.—Four.

Type specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Moderately small dactylogyrid provided with a relatively thick cuticle which is smooth on the body proper and transversely rugose on the peduncle; length 0.263 mm (0.248-0.270 mm), greatest width 0.084 mm (0.072-0.090 mm). Eye spots four, approximately equal in size, members of the anterior pair slightly farther apart than those of the posterior pair. Cephalic lobes very conspicuous; anterior cephalic margin cleft medially. Pharynx circular in outline (dorsal view) and 0.025 mm (0.021-0.029 mm) in transverse diameter. Peduncle short and broad; haptor ovate in outline (side view). Each anchor composed of 1) a base with well-defined roots, 2) a solid shaft, and 3) a solid point (fig. 53). Anchor length 0.041 mm, greatest width of base 0.018 mm. Vestigial ventral bar amphi-attenuate (fig. 55). Dorsal bar length 0.025 mm (fig. 54). Hooks fourteen in number, approximately equal in size, and normal in arrangement (Mizelle, 1938). Each hook with a prominent oval base, a solid shaft somewhat larger than the base, an opposable piece, and a sickle-shaped termination. Hook length about 0.022 mm (figs. 58, 59). Ovary pyriform in outline and situated anterior to the elongate testis which is rounded anteriorly, pointed posteriorly and measures about $2\frac{1}{2} \times$ the length of the ovary. Vitellaria well developed as two lateral bands which are confluent at both ends, and extend from the posterior border of the pharynx to the peduncle. Vagina not observed with certainty. Copulatory complex well developed and consisting

of a proximally articulate cirrus and accessory piece (figs. 56, 57). Cirrus tubular and gently curved; length 0.027 mm (0.025-0.029 mm). Accessory piece with a recurved process which arises on the distal half of the shaft; accessory piece length 0.023 mm (0.021-0.025 mm). Seminal vesicle and prostates well developed.

The closest relative of *Dactylogyrus distinctus* n. sp., from standpoint of the cirrus is *D. microphallus* (Mueller, 1938; Pl. 4, fig. 12). However, the accessory piece and haptor armament of *D. microphallus* (Mueller, 1938; Pl. 4, fig. 11) differ markedly from corresponding structures of *D. distinctus* n. sp. (figs. 53-55, 57-59). The anchor of *D. tenax* (Mueller, 1938; Pl. 4, fig. 27) is similar to that of *D. distinctus* n. sp.

Dactylogyrus dubius n. sp.

Figs. 60, 61

Host and locality.—*Notropis cornutus frontalis*, Fish Creek, Bayfield Co., Wis.

Specimens studied.—One.

Type specimen.—Type, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Relatively small dactylogyrid provided with a very thin, smooth, transparent cuticle. The single available specimen was minus the haptor so that no measurements of the body length or haptor armament were possible. Greatest width of body 0.112 mm. Eye spots four, members of both pairs approximately of equal size and about the same distance apart. Cephalic lobes inconspicuous; anterior cephalic margin cleft medially. Pharynx ovate, everted and 0.036 mm in anteroposterior diameter. Ovary ovate and situated anterior to the smaller, ovate testis. Vitellaria well developed, extending from base of pharynx to posterior portion of specimen; vitellarial bands confluent throughout their length. Vagina on left side of body immediately posterior to the copulatory complex. Copulatory complex well developed and consisting of a proximally articulate cirrus and accessory piece (figs. 60, 61). Cirrus composed of an elongate, slender base from which the simply curved shaft arises near its (base) midlength; cirrus length 0.045 mm. Accessory piece curved and parallel with the cirrus shaft except for the extreme tip of the latter. A transverse process, which arises from the accessory piece near its midlength, is bent laterad to the level of the lower surface of the cirrus shaft. Accessory piece length 0.031 mm. Seminal vesicle well developed; prostates not observed.

The description of a species from a single fragment of a specimen is recognized as not being highly satisfactory. However, since differentiation of species of *Dactylogyrus* is so dependent on the copulatory complex, which was present in our fragment, it was considered safe to proceed especially since a comprehensive work on this genus is contemplated in the near future. *D. dubius* possesses a copulatory complex which is unlike that of any described species of *Dactylogyrus*.

Dactylogyrus extensus Mueller and Van Cleave, 1932

Figs. 62-69

Host and locality.—*Cyprinus carpio*, Lake Pepin, Wis.

Previously reported host and locality.—*Cyprinus carpio*, Oneida Lake, N. Y. (Mueller and Van Cleave, 1932).

Specimens studied.—Thirteen.

Comparative description.—Relatively large dactylogyrids provided with a moderately thick, transparent cuticle; length 1.296 mm (0.990-1.584 mm) "about 1.5 mm long," greatest width 0.158 mm (0.126-0.180 mm) "0.1 mm in diameter." Eye spots four, members of the posterior pair slightly larger and usually closer together than those of the anterior pair. Cephalic lobes rather prominent, anterior cephalic margin cleft medially; pharynx subcircular to ovate in outline (dorsal view) and 0.069 mm (0.050-0.083 mm) in transverse diameter. Peduncle relatively long and narrow; haptor subhexagonal in outline. Each anchor composed of a deeply cleft base with well-differentiated roots, a solid shaft, and a solid point. Distal portion of anchor base characteristically with a perforation; anchor wings enclosing area in which perforation occurs (fig. 62). Anchor length 0.081 mm (0.075-0.088 mm), greatest width of base 0.044 mm (0.033-0.046 mm). Dorsal bar, variable in shape, with enlarged ends, and usually containing a cavity (figs. 63, 64). Dorsal bar length 0.047 mm (0.042-0.050 mm). Vestigial ventral bar

not observed. Hooks fourteen in number, subequal in length, and normal in arrangement (Mizelle, 1938). Each hook composed of a large, hollow base, a solid shaft which is shorter than the base, and a sickle-shaped termination (figs. 68, 69). Hook length 0.031-0.035 mm "length of about 0.035 mm." Gonads situated near body midlength and ovate in outline; ovary situated anterior to, and less elongate than the testis. Vitellaria well developed and extend from a level immediately posterior to the pharynx to a point near the proximal border of the peduncle. Copulatory complex highly developed and consisting of a cirrus and accessory piece which are basally articulate with each other (figs. 65, 66, 67). Cirrus prominent, shaft well defined, and simply curved. Accessory piece relatively straight with a knob-like or a ragged enlarged termination. Cirrus length 0.071 mm (0.054-0.083 mm); accessory piece length 0.055 mm (0.042-0.071 mm). Seminal vesicle well defined; prostates not observed with certainty.

D. extensus is one of the larger dactylogyrids recorded. It is readily distinguished from other forms by its characteristic dorsal bar and anchors. The copulatory complex is simple morphologically and resembles that of *Cleidodiscus pricei* of the subfamily *Tetraonchinae*. The cirrus and accessory piece were figured erroneously by Mueller and Van Cleave, 1932 (Pl. 18, fig. 13):

Dactylogyrus lineatus n. sp.

Figs. 70-77

Host and localities.—*Semotilus a. atromaculatus*, Fish Creek, Bayfield Co. and Pine River, Clarence Co., Wis.

Specimens studied.—Two.

Type specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Moderately small dactylogyrids provided with an exceedingly thin cuticle; length 0.348 mm (0.288-0.407 mm), greatest width 0.074 mm (0.072-0.075 mm). Eye spots four, members of the posterior pair slightly larger than those of the anterior pair, members of each pair about the same distance apart. Cephalic margin conspicuously lobed; pharynx subcircular in outline (dorsal view) and 0.028 mm (0.025-0.029 mm) in transverse diameter. Peduncle short and broad; haptor irregularly ovate in outline. Each anchor composed of 1) a base with well-defined roots, 2) a solid shaft, and 3) a solid point. Superficial root of anchor bases folded laterally (fig. 70). Anchor wing present on distal portion of base and proximal portion of shaft. Anchor length 0.037 mm (0.036-0.038 mm), greatest width of base 0.020 mm (0.018-0.021 mm). Vestigial ventral bar present as a thin line, and 0.018 mm in length (fig. 72). Dorsal bar with rounded ends, length 0.034 mm (0.031-0.038 mm) (fig. 71). Hooks fourteen in number, approximately equal in length, and normal in arrangement (Mizelle, 1938). Hook lengths, 0.020-0.022 mm (figs. 75-77). Ovary relatively small, ovate in outline (dorsal view) and situated anterior to the more elongate testis. Vitellaria highly developed and extending from posterior border of pharynx to peduncle. Vagina not observed with certainty. Copulatory complex well defined and consisting of a cirrus and accessory piece (figs. 73, 74). Cirrus composed of large base and a relatively long shaft; cirrus length 0.036 mm (0.031-0.040 mm). Accessory piece gently curved, possesses a conspicuous lateral projection, and articulated to the cirrus base; length 0.032 mm (0.031-0.033 mm). Seminal vesicle well developed, prostates not observed with certainty.

The closest relative of this species is very difficult to determine. The cirrus resembles somewhat that of *D. amblopi* (Mueller 1938, Pl. 3, fig. 29) and *D. microphallus* (Mueller 1938, Pl. 4, fig. 12). The accessory piece, however, is quite different from any known American species. The folded, superficial roots of the anchor bases together with the characteristic dorsal bar and the very lightly developed vestigial bar are characteristic.

Dactylogyrus microphallus Mueller, 1938

Host and locality.—*Semotilus a. atromaculatus*, Fish Creek, Bayfield Co., Wis.

Previously reported host and locality.—*Semotilus atromaculatus*, French Creek, near Panama, N. Y. (Mueller, 1938).

Specimens studied.—Three.

Comparative description.—Moderately small dactylogyrids provided with a moderately thick cuticle; length 0.336 mm (0.270-0.414 mm) "0.5 mm long;" greatest width 0.075 mm "0.08 mm wide." Eye spots four, approximately equal in size, members of the anterior pair farther apart than those of the posterior pair. Cephalic lobes conspicuous; pharynx circular to ovate in outline (dorsal view) and 0.027 mm (0.025-0.029 mm) in transverse diameter. Peduncle short and broad; haptor irregularly hexagonal in outline. Each anchor composed of 1) a base with well-differentiated superficial and deep roots, 2) a solid shaft, and 3) a solid point. Anchor length 0.032 mm (0.029-0.033 mm) "Anchors 0.035 mm in greatest straight dimension," greatest width of base 0.020 mm (0.019-0.021 mm). Dorsal bar as originally described (Mueller, 1938, Pl. 4; fig. 14). Dorsal bar length 0.026 mm (0.025-0.027 mm) "0.035 mm long." Hooks fourteen in number, subequal in length, and normal in arrangement (Mizelle, 1938). Each hook with an inflated oval base, a solid shaft somewhat longer than the base, a small opposable piece, and a sickle-shaped termination. Hook lengths 0.018-0.022 mm in length "0.021 mm long." Ovary relatively large, irregularly ovate and situated anterior to the more elongate testis. Vitellaria well developed and scattered throughout most of the body length posterior to the pharynx. Vagina not observed with certainty. Copulatory complex as originally described (Mueller, 1938, Pl. 4; fig. 12). Cirrus length 0.036 mm (0.035-0.038 mm) "0.035 mm long;" accessory piece length 0.025 mm (0.024-0.026 mm). Seminal vesicle well defined and apparently filled with spermatozoa; prostates not observed.

***Dactylogyrus pyriformis* n. sp.**

Figs. 78-86

Host and locality.—*Notropis cornutus frontalis*, Fish Creek, Bayfield Co., Wis.

Specimens studied.—One.

Type specimen.—Type, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Moderately small dactylogyrid provided with a transparent cuticle of average thickness; length 0.414 mm, greatest width 0.079 mm. Eye spots four, approximately equal in size, and members of each pair about the same distance apart. Cephalic lobes inconspicuous; pharynx subcircular in outline (dorsal view) and 0.026 mm in transverse diameter. Peduncle short and broad; haptor subhexagonal in outline. Each anchor composed of 1) a base with well-differentiated superficial and deep roots, 2) a solid shaft, and 3) a solid point (figs. 78-80). Anchor wings not observed; anchor length 0.040 mm, width of base 0.015 mm. Vestigial ventral bar similar to that of *D. vannus* n. sp. (fig. 89); length 0.027 mm. Dorsal bar gently curved posteriorly and possessing a notch on the posterior border near each end (fig. 81). Hooks fourteen in number, subequal in length, and normal in arrangement (Mizelle, 1938). Hooks morphologically similar to those of *D. vannus* n. sp.; hook lengths, 0.022-0.024 mm (figs. 85, 86). Ovary irregularly transversely ovate and situated anterior to the elongate testis. Vagina not observed. Copulatory complex composed of a cirrus (fig. 83) similar to that described for *D. vannus* n. sp. (fig. 90) and an accessory piece articulated with the base of the cirrus and possessing a unguiculate structure at the distal end (fig. 84). Cirrus length 0.049 mm; accessory piece length 0.015 mm. Vitellaria well developed and distributed on either side of the body as two lateral bands, which are confluent anteriorly behind the eye spots and posteriorly near the peduncle. Seminal vesicle and prostates well developed.

Although the morphology of the cirrus, vestigial ventral bar (fig. 82), and hooks of *D. pyriformis* are very similar to those of *D. vannus* n. sp., the morphology of the dorsal bar, anchors, and characteristic accessory piece are not even remotely similar to those of *D. vannus*, its apparent closest relative.

***Dactylogyrus vannus* n. sp.**

Figs. 87-93

Host and locality.—*Notropis cornutus frontalis*, Fish Creek, Bayfield Co., Wis.

Specimens studied.—One.

Type specimen.—Type, Univ. of Notre Dame, Notre Dame, Ind.

Description.—Relatively small dactylogyrid provided with a smooth, moderately thick cuticle; length 0.432 mm, greatest width 0.092 mm. Eye spots four, approximately equal in size, members of each pair about the same distance apart. Cephalic lobes conspicuous, median anterior cephalic margin deeply cleft; pharynx subcircular in outline (dorsal view) and 0.027 mm in transverse diameter. Peduncle short and narrower than body proper; haptor irregularly ovoid in outline. Each anchor composed of 1) a base with well-differentiated roots, 2) a solid shaft, and 3) a solid point (fig. 87). Anchor shafts unevenly curved and presenting a distinct angle near the midlength. Anchor wings not observed; superficial root of anchor base greatly developed. Dorsal anchor length 0.031 mm, greatest width of base 0.020 mm. Vestigial ventral bar with a median projection on the anterior border; length 0.029 mm (fig. 89). Dorsal bar remotely similar to ventral bar in morphology; dorsal bar length 0.031 mm (fig. 88). Hooks fourteen in number, subequal in length, and normal in arrangement (Mizelle, 1938). Each hook with an elongate-ovate base, a solid, slender shaft, and a small opposable piece with a sickle-shaped termination (figs. 92, 93). Hook lengths 0.020-0.024 mm. Gonads elliptical in outline, approximately the same size, testis posterior. A large chitinated egg was observed adjacent to the copulatory complex. Vagina not observed. Copulatory complex composed of 1) a long, tubular cirrus with a well-defined base and 2) a fan-shaped accessory piece articulated with the cirrus base (figs. 90, 91). Cirrus length 0.047 mm; accessory piece length 0.018 mm. Seminal vesicle fairly well developed; prostates not observed with certainty. Vitellaria well developed and distributed as two lateral bands.

The closest relatives of *D. vannus*, from the standpoint of the cirrus, are *D. pyriformis* n. sp. and *D. cornutus* (Mueller, 1938). The accessory piece of *D. vannus* is fan-shaped and very different from any described species of *Dactylogyrus*. The angular anchor shafts are remotely similar to those of *D. confusus* (Mueller, 1938).

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EXPLANATION OF FIGURES

Figs. 1-3. *Cleidodiscus brachus*.—1. Ventral anchor; 2. Dorsal anchor; 3. Haptoral hook.

Fig. 4. *C. floridanus*.—Accessory piece.

Figs. 5-17. *Urocleidus chrysops*.—5, 6. Dorsal bar; 7, 8. Ventral bar; 9-11. Hooks; 12. Ventral anchor; 13. Dorsal anchor; 14, 15. Cirrus; 16, 17. Accessory piece.

Figs. 18-20. *U. minus*.—18. Cirrus; 19. Accessory piece; 20. Hook.

Figs. 21-28. *Murraytrema copulata*.—21. Dorsal anchor; 22. Ventral anchor; 23. Hook; 24, 25. Cirrus; 26, 27. Accessory piece; 28. Appendage.

Figs. 29-39. *Dactylogyrus attenuatus*.—29. Anchor; 30, 31. Dorsal bar; 32. Ventral bar; 33, 34. Cirrus; 35, 36. Accessory piece; 37-39. Hooks.

Figs. 40-46. *D. bulbus*.—40. Anchor; 41. Dorsal bar; 42-44. Ventral bar; 45, 46. Hooks.

Figs. 47-52. *D. claviformis*.—47. Anchor; 48. Dorsal bar; 49. Cirrus; 50. Accessory piece; 51, 52. Hooks.

Figs. 53-59. *D. distinctus*.—53. Anchor; 54. Dorsal bar; 55. Ventral bar; 56. Cirrus; 57. Accessory piece; 58, 59. Hooks.

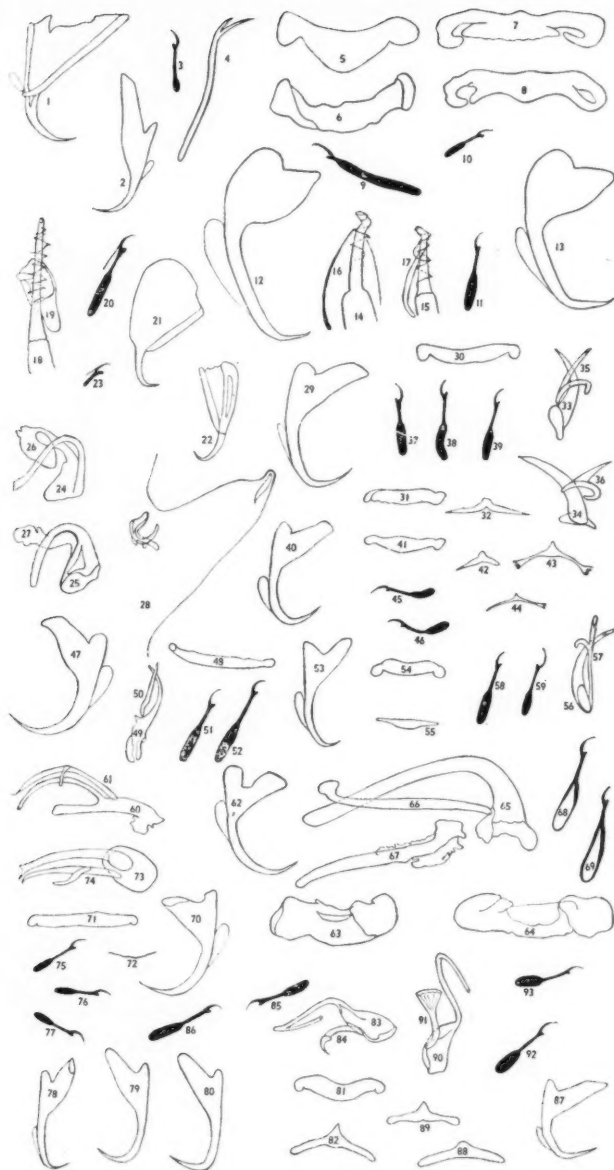
Figs. 60, 61. *D. dubius*.—60. Cirrus; 61. Accessory piece.

Figs. 62-69. *D. extensus*.—62. Anchor; 63, 64. Dorsal bar; 65. Cirrus; 66, 67. Accessory pieces; 68, 69. Hooks.

Figs. 70-77. *D. lineatus*.—70. Anchor; 71. Dorsal bar; 72. Ventral bar; 73. Cirrus; 74. Accessory piece; 75-77. Hooks.

Figs. 78-86. *D. pyriformis*.—78-80. Anchor; 81. Dorsal bar; 82. Ventral bar; 83. Cirrus; 84. Accessory piece; 85, 86. Hooks.

Figs. 87-93. *D. vannus*.—87. Anchor; 88. Dorsal bar; 89. Ventral bar; 90. Cirrus; 91. Accessory piece; 92, 93. Hooks.



Head Organs and Cephalic Glands of *Cleidodiscus mirabilis*¹

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Detailed information on the genus *Cleidodiscus* Mueller, 1934, has been confined heretofore to taxonomy and general morphology (Mueller, 1934, 1937; Mizelle, 1938; Mizelle and Cronin, 1943). Head organs and cephalic glands were selected presently for detailed study because of a paucity of information concerning them, their conspicuous nature in life and confinement to a small area.

Specimens were collected from the gills of the yellow cat (*Pilodictis olivaris* Rafinesque) and the blue cat *Ictalurus furcatus* Cuvier and Valenciennes which were recovered from Fort Loudoun Lake, and the Tennessee River at Knoxville, and Lenoir City, Tennessee. Live specimens were obtained from the majority of the hosts which were examined within thirty minutes after removal from the lake. Additional live material was provided for four to six hours by aeration. The aerator consisted of a one-liter suction flask two-thirds full of water and fitted with a rubber stopper containing a single hole through which air was drawn by suction via a glass tube extending to the bottom of the flask.

Dead specimens, removed from hosts dead for several hours, were fixed in Carnoy's solution. Some of these were stained with Delafield's hematoxylin and mounted in Piccolyte;³ others were mounted unstained in glycerine-chromate gel (Yetwin, 1944). Living specimens were fixed in Carnoy's, Zenker-formol, and Flemming's solutions. Zenker-formol fixed specimens proved the most satisfactory since there was less shrinkage and more cellular detail was visible. Specimens for histological study were imbedded in paraffin and sectioned transversely, frontally, or sagittally, stained with Heidenham's iron hematoxylin, and mounted in piccolyte.

Specimens for examination alive were mounted in water on slides, under cover slips ringed with vaseline, and for the most part remained alive for two to three hours. Examination was made with the phase-contrast microscope. Best examination results were obtained with the Spencer dark contrast-medium 4 mm. objective and with the dark contrast-medium 1.8 mm. oil immersion objective. Photomicrographs were made of the head region of living whole mounts and compared with similar photomicrographs of fixed whole mounts (Figs. 1 and 2). The pictures were made with the phase-contrast microscope

¹ Contribution from the Department of Zoology and Entomology, University of Tennessee.

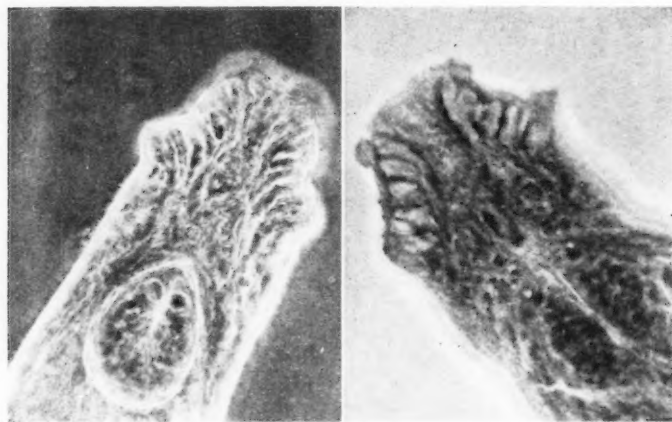
² Present address: Sterling-Winthrop Research Institute, Rensselaer, New York.

³ A synthetic resin obtainable from the General Biological Supply Company, Chicago, Illinois.

using the 4 mm. dark contrast-medium objective. Exposures were made at ten inches from the eyepiece for one-half second with the Bausch and Lomb research ribbon filament lamp at nine-tenths greatest intensity. Eastman Tri-X Pan film was used, and it was developed in Eastman D.K. 76 developer.

Semi-diagrammatic drawings were made of the head region showing the cephalic glands, ducts, and head organs in their relationship to the pharynx (Fig. 3).

The head organs of the prohaptor usually consist of four to six pairs and are situated on the antero-lateral margins of the head. Although in a few instances a thirteenth organ was observed on one side, never were less than



Figs. 1, 2. Photomicrographs of head organs in *Cleidodiscus mirabilis*, 500 \times .—1. Live specimen (left); 2. Fixed specimen (right).

four pairs observed (Fig. 3). The organs are thickened elliptical tubes of from 0.009 to 0.015 mm. in length and 0.002 to 0.006 mm. in width. They are connected at their proximal end to a duct which runs posteriad to the cephalic glands. The head organs were seen extruding the mucoid secretions of the cephalic glands from varying pairs of the organs at different times, indicating the possible presence of some control mechanism. When examined with the phase-contrast microscope, the head organs were seen to contain a thread-like material, similar to the contents of the rhabdite-glands of certain Turbellaria. In fixed specimens the organs showed a granular composition. This granular material is probably a coagulation of the threadlike material seen in the living specimens and the result of the fixation of the rhabdite filaments. It is not cellular.

The cephalic glands are situated just anterolaterally to the pharynx. They are composed of several lobed structures which when examined in serial sections proved to be syncytial masses, each with several prominent nuclei. The

lobes are 0.007 to 0.014 mm. in diameter with all nuclei about 0.002 mm. in diameter. The nuclei and granules in the cell both stained dark although the nuclei were several times larger than the granules. The glands are all connected by ducts with the head organs, and the ducts appeared to be extensions of the gland cells. The glands on each side of the animal supply their respective head organs.

The general structure and anatomy of the prophaptor of *Cleidodiscus mirabilis* is certainly not unusual or strikingly different from many other forms of Monogenea (such as *Tetraonchus* and *Ancyrocephalus*). Similar structures with similar functions are to be found in certain of the Turbellaria-like *Rhynchomesostomum* (Hyman, 1951).

Almost all of the details of structure of these animals could be seen in living specimens with the phase-contrast microscope and these observations were corroborated by study of fixed and sectioned animals.

SUMMARY

Specimens of *Cleidodiscus mirabilis* were obtained from the catfish and the finer structure of the head organs and cephalic glands studied.

Fixation in Zenker-formol proved best for sectioned material and in Carnoy's for whole mounts.

The head organs were found to consist of four to six pairs of ducts opening to the antero-lateral margins of the prohaptor.

The head organs are connected to syncytial masses forming the cephalic glands.

The cephalic glands are lobate in outline and are situated near the pharynx.

The cephalic glands produce a mucoid secretion of rhabdite nature which aids in attachment of the prohaptors for feeding and locomotion.

Examination of living material with the phase-contrast microscope aided materially in this study.

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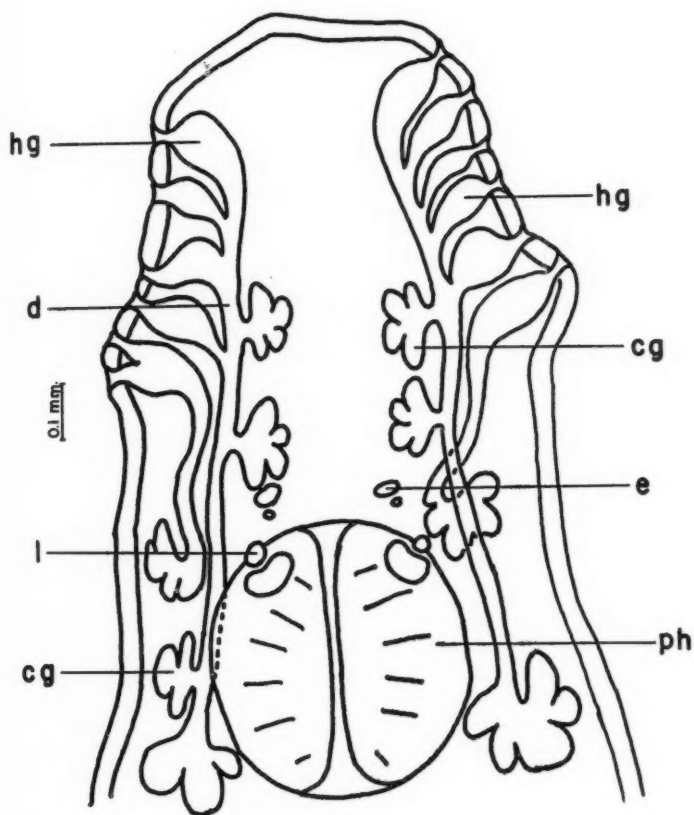


Fig. 3.—Semi-diagrammatic illustration of cephalic glands, ducts, and head organs in relation to the pharynx.

Catenotaenia californica, sp. nov., a Cestode of the Kangaroo Rat, *Dipodomys panamintinus mohavensis*

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Reports of the cestode genus *Catenotaenia* in North American hosts are quite meager. Apparently only two species, *Catenotaenia linsdalei* McIntosh and *C. pusilla* (Goeze, 1782), have been described and reported from several rodents in North America (McIntosh, 1941; Joyeux and Baer, 1945; Voge, 1948; Chandler and Melvin, 1951). Recent examination of some cestodes from the Panamint Kangaroo Rat, taken in Southern California by Mr. D. J. Doran,² revealed that this rodent also harbors a *Catenotaenia* species. Direct comparison of the writer's material with the type specimen of *C. linsdalei* McIntosh, kindly loaned by Dr. E. W. Price, Curator of the Helminthological Collection, United States National Museum, and with a specimen of *C. pusilla* (Goeze, 1782) kindly loaned by Dr. A. C. Chandler, indicated that the worms from the Panamint Kangaroo Rat represented a different species. Comparison with the published descriptions of other members of this genus showed that the present material represents a new species. A description follows:

Catenotaenia californica, sp. nov.

Strobila thin and of moderate length, ranging from $26\frac{1}{2}$ mm. to 82 mm. in length and 3.3 mm. in maximum width. The mature proglottid is usually longer than broad, averaging 0.996 mm. by 0.922 mm., however, this nearly square shape varies rapidly in both directions along the strobila, the segments being broader than long anteriorly and longer than broad posteriorly. The mature proglottids range in size from 0.748 to 1.13 mm. in width by 0.870 mm. to 1.26 mm. in length. The gravid proglottids vary from 1.25 to 3 times as long as broad; the length ranges from 1.85 to 3.3 mm. (average 2.68 mm.), and the width ranges from 1.13 mm. to 1.65 mm. (average 1.43 mm.). The proglottids are individually wider posteriorly than anteriorly and are markedly craspedote in both living and preserved specimens.

The scolex ranges from 150 μ to 200 μ in diameter (averages 181 μ). A rostellum and hooks are lacking. Four shallow suckers are present. The outside diameter of the suckers ranges from 68 μ to 110 μ (average 88.8 μ), and the inside diameter ranges from 30 μ to 70 μ (averages 53.6 μ).

The neck of the organism is constricted immediately posterior to the scolex, ranging in width from 120 μ to 200 μ (average 150 μ). The neck is short, ranging from 392 μ to 974 μ (average 764 μ) (Fig. 1).

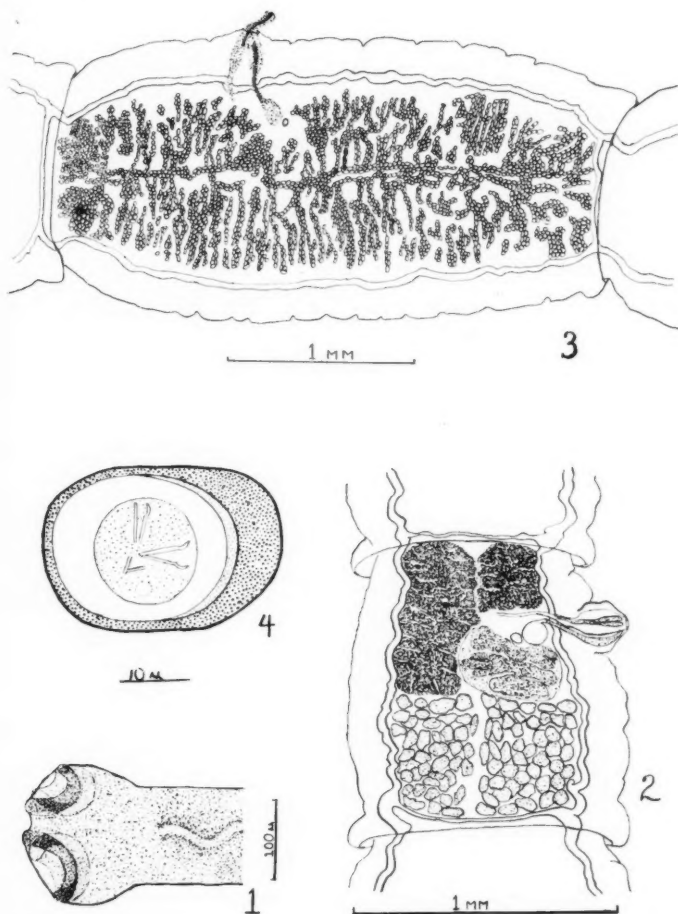
The excretory system begins in the neck as a single canal which branches into two longitudinal canals in the anterior strobila or as a double canal posterior to the scolex. At the posterior end of each proglottid there is a transverse commissure between the two longitudinal excretory canals. The diameter of the longitudinal canals is about 40 μ , that of the transverse commissure is about 20 μ .

¹ The author wishes to thank Dr. Clark P. Read for his help during the preparation of the manuscript.

² Thanks are given to Dr. D. J. Doran for the information pertinent to the identity of the hosts and their place of capture.

The genital pores are irregularly alternate and located in the anterior quarter of the mature segment and in the anterior third of the gravid segment. The genital atrium is frequently marked by a protuberance.

The male reproductive system is contained in the posterior half of the segment and includes 72 to 90 oval testes arranged in two bands, one band in each lateral half of the segment (Fig. 2). The testes average $40\ \mu$ by $60\ \mu$ in size. The testicular



Figs. 1-4. *Catenotaenia californica*, sp. nov.—1. Scolex. 2. Mature proglottid. 3. Gravid proglottid. 4. Mature ovum. (All figures drawn with the aid of a camera lucida.)

anlage appear in the fourteenth proglottid and are developed in the thirtieth proglottid. The testes are quite atrophied in the forty-fifth proglottid. The unarmed cirrus is $78\ \mu$ to $150\ \mu$ in length and $20\ \mu$ to $38\ \mu$ in width. The cirrus is frequently protruded. The prominent cirrus pouch is oval, $140\ \mu$ to $154\ \mu$ long and $60\ \mu$ to $80\ \mu$ in width, lateral to the longitudinal excretory canal. A seminal vesicle is apparently lacking. The vas deferens can be traced only to the center of the segment; loops are apparently not present in the vas deferens.

The female reproductive system consists of a bilobed, follicular ovary in the anterior half of the segment, a vagina, seminal receptacle, a small shell gland, and an oval, deeply lobed vitellarium (Fig. 2). The ovary first appears in the thirty-first segment and is atrophied in the forty-eighth segment. The organ is composed of an aporal arm extending posteriorly to the testes and a poral arm extending to the level of the anterior margin of the genital sinus. The arms of the ovary are deeply lobed, and the arms are distinctly separated. The vagina opens at the postero-lateral border of the cirrus pouch; it runs medially to the seminal receptacle which is an oval or round structure, $110\ \mu$ to $140\ \mu$ in diameter, located at the level of the posterior border of the genital sinus. Immediately medial and posterior to the seminal receptacle is the small shell gland, $24\ \mu$ to $30\ \mu$ in diameter. The vitellarium is posterior to the seminal receptacle and fills the space between the latter and the testes on the poral side of the segment. In the gravid segment the uterus consists of a median, longitudinal stem with approximately 25 to 30 lateral branches on either side (Fig. 3). The entire reproduction complex, with the exception of the terminal portions, is contained within the area medial to the excretory canals. In the gravid segment the vagina, seminal receptacle, vas deferens, and cirrus are not atrophied as are the other components of the reproductive system.

The mature ovum is oval, $14\text{--}15\ \mu$ in diameter and is enclosed within an ovoid shell, $23\ \mu$ by $33\ \mu$ in diameter. One pole of the egg shell is much thicker than the other, being $6\ \mu$ to $14\ \mu$ in thickness while the remainder of the shell is approximately $1.5\text{--}2\ \mu$ thick. The ovum is usually found free inside the shell (Fig. 4) but may sometimes be tightly enclosed by the shell. There is an inner shell membrane, $2\ \mu$ in thickness discernible at the heavy pole of the shell; occasionally a third membrane, adhering to the surface of the ovum, may be observed. When all three membranes are observed the middle membrane appears to be radially striated. Six hooks are present and are seven micra in length by $\frac{1}{2}$ micron in width.

Habitat: Small intestine of the kangaroo rat.

Type Host: *Dipodomys panamintinus mohavensis* Hall.

Other Hosts: *Dipodomys mohavensis*, *D. morroensis*.

Type locality: Lovejoy Butte, 15 miles southeast of Palmdale, Calif.

Other localities: Llano Road, 2 miles northwest of Victorville, California; Moro Bay, California.

Type specimen: United States National Museum, Helminthological Collection, Number 47559.

Cotypes: In collections of Dr. C. P. Read, Dept. Zoology, University of California, Los Angeles, Dr. Yost U. Amrein, Dept. Zoology, Pomona College, and in the writer's collection.

DISCUSSION

The genus, *Catenotaenia*, was erected by Janicki (1904) to include two cestodes, *Taenia pusilla* Goeze and *T. dendritica* Goeze. The diagnosis of this genus included: rostellum lacking, scolex unarmed, ovary in anterior half of segment and numerous testes in posterior half of segment. Since the founding of the genus there have been, including the present species, nine additional species described: *C. lobata* Baer, 1925; *C. symmetrica* Baylis, 1927; *C. oranensis* Joyeux and Foley, 1930; *C. rhombomidis* Schulz and Landa, 1934; *C. geosciuri* Ortlepp, 1938; *C. capensis* Ortlepp, 1940; *C. linsdalei* McIntosh, 1941; *C. ris* Yamaguti, 1942 (Joyeux and Baer, 1945); *C. californica*.

It appears that *C. symmetrica*, because of the lack of a definite uterus, is more properly assigned to the genus *Oochoristica* as suggested by Meggitt (1934) and confirmed by Perry (1939), Hughes (1940), and Joyeux and Baer (1945).

C. ris has been considered as synonymous with *C. dendritica* by Fuhrmann and Baer (Joyeux and Baer, 1945). Thus, it seems that there are nine valid species in the genus, *Catenotaenia*.

These species may be separated into two groups according to the excretory system; in the major group are seven species, characterized by an excretory system of two primary, ventral longitudinal canals containing a single posterior transverse commissure, with or without secondary anastomoses, and at times a pair of small, dorsal excretory canals without anastomoses; in the minor group are two species, *C. lobata* and *C. capensis*, that contain 18 to 20 longitudinal canals that are joined by numerous anastomoses. In connection with this discussion of the excretory system, it should be mentioned that Ortlepp (1938) in his description of *C. geosciuri* mentions only two ventral, longitudinal canals while in his description (1940) of *C. capensis* he states that in both *C. capensis* and *C. geosciuri* the excretory system consists of numerous longitudinal canals and anastomoses. Was Ortlepp mistaken in his original description of *C. capensis*? It would not appear so, since Joyeux and Baer (1945) describe the excretory system of *C. geosciuri* thus: "Le système excréteur ne présente pas de ramifications secondaires. . . ."

Our specimen thus falls into the major group, for cross-sections disclose only two longitudinal excretory canals, and, although a careful search has been made for a pair of small dorsal canals, none have been found. Of this group the members may be divided roughly into three groups on the basis of the number of testes. Testes number 70 to 150 (*C. californica*, *C. linsdalei*, *C. pusilla*), testes number 140 to 250 (*C. dendritica*, *C. geosciuri*, *C. oranensis*), testes number over 400 (*C. rhombomidis*).

Our cestode is morphologically closely related to *C. linsdalei* and *C. pusilla*. *C. californica* may be differentiated from *C. linsdalei* by: 1) The number of uterine branches (25-30 for *C. californica*, 40-50 for *C. linsdalei*); 2) size of the shell gland (24-30 μ in *C. californica*, 50 μ in *C. linsdalei*); 3) size of the seminal receptacle (110-140 μ in *C. californica*, 85 μ in *C. linsdalei*); 4) the uterus may be seen developing anterior to the ovary in *C. linsdalei* but not in *C. californica*.

The differentiation from *C. pusilla*, the most closely related species morphologically, is: 1) No small dorsal excretory ducts can be demonstrated in cross-sections of *C. californica*; 2) the shell gland in *C. pusilla* lies more medially and anterior than it does in *C. californica*; 3) the genital ducts disappear in the gravid segment of *C. pusilla* while they are prominent in *C. californica*; 4) the number of uterine branches in *C. pusilla* ranges from 16-20; in *C. californica* the number of branches ranges from 25-30; 5) the testes in *C. pusilla* are in a single field in the posterior third of the segment, and in *C. californica* the testes are arranged in two lateral fields in the posterior half of the segment.

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Rate of Development, Viability, Vigor, and Virulence of *Ascaridia galli* Ova Cultured Respectively in Air and in Water¹

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Knowledge of the rate of development, resistance, and viability of nematode eggs has been accumulating for nearly a century. Most of the work has been concerned with the ascarids of pig and man, but some studies have been made on the rate of development and viability of the eggs of *Ascaridia galli* (Schränk, 1788). McRae (1935) reported that the ova of *A. galli* did not develop beyond the tadpole stage when kept in an atmosphere 40 to 50 per cent saturated, and only an occasional ovum developed beyond the morula stage at this relative humidity. Ova kept in 82 to 86 per cent relative humidity at 22° C. developed more slowly than those in water, whereas ova kept in 100 per cent relative humidity at 30° C. developed at the same rate as did those in water. Ackert (1931) reported the optimum developmental temperature for *A. galli* to range from 30° to 33° C. Twelve hours exposure to 43° C. proved to be lethal for these ascarid eggs in all stages of development. Such environmental factors as temperature, shade, and depth below surface of the ground influenced the development and survival of *A. galli* ova (Ackert and Cauthen, 1931; Levine, 1937).

Age of infective ova is also a factor in their viability. Ackert et al. (1947) reported that egg cultures of *A. galli* incubated in water at 30° to 33° C. for 36 days proved to be more viable than eggs of a 120-day-old culture. Their criterion for judging viability was the average lengths of the worms recovered from experimental chickens subsequent to feeding eggs from the two types of cultures. Todd et al. (1950) used the criterion of failure on the part of the host to gain weight subsequent to infection with *A. galli* as an indication of virulence of the nematode, whereas an increase in worm numbers accompanied by an increase in host weight indicated optimum viability of the infective larvae. They reported that the greatest host injury resulted from feeding chickens infective eggs 14-21 days old that the virulence of the parasite decreased as the infective eggs aged.

The present paper reports the results of experiments designed to compare the rates of development, viability, vigor, and virulence of larvae developing from *A. galli* ova cultured respectively in 90 per cent relative humidity and in shallow water.

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MATERIALS AND METHODS

Ova of *A. galli* used in these experiments were obtained from the uteri of living female worms. The egg cultures for each of the four experiments were prepared in the following manner: A square, measuring 6 x 6 mm., was scratched on each of 10 glass slides with the aid of a diamond point pencil. A thin layer of Meyer's egg albumen was smeared on 5 of the slides which were to be placed in water. The albumen acted as an adhesive and prevented the eggs from floating off the slides. A platinum wire loop was used to transfer $200 \pm$ eggs to each of the 10 slides. The number of eggs per slide was ascertained by an actual count made with the aid of a compound microscope. Excess numbers of eggs were removed with a small piece of moist filter paper. The egg masses on the 5 slides to be placed in 90 per cent relative humidity were permitted to dry, care being taken not to allow the eggs to become too dry. Such preliminary drying of the egg masses resulted in their firmly adhering to the surface of the slide.

The 5 slides containing the eggs to be cultured in water were placed in Petri dishes and covered with tap-water to a depth of 1 to 2 mm. The Petri dishes were then placed in an incubator maintained at 30° C.

The 5 slides containing the eggs to be cultured in air were placed in humidity chambers in which the air was maintained at 90 per cent relative humidity by chemical means. The humidity chambers were glass jars 5 inches in diameter by $5\frac{1}{2}$ inches high and covered with screw caps. Inside the jars were glass supports made by fusing 4 right-angle glass rods. The slides containing the eggs to be cultured were placed on a wire screen which was supported above the chemical solution by the glass rod frame. Each jar contained about 300 cc. of a sulfuric acid solution prepared to maintain a relative humidity of 90 per cent (Buxton and Mellanby, 1934).

The development of the eggs of both types of cultures was observed at 48-hour intervals for a period of 30 days. The various stages were determined with the aid of the illustrations by Ackert (1931). Because of the irregularity in the rate of development as well as the numerous developmental stages present at one time, the following developmental classification of the eggs was adopted: 1-cell, 2-4-cell, 5-8-cell, 9-32-cell, early morula, late morula, tadpole, vermiform, and coiled embryo stage.

The chickens used in these experiments to test the vigor and virulence of the larvae in the two types of cultures were straight run Single Comb White Leghorns purchased from an approved commercial hatchery. They were received as day-old chickens, weighed, separated into two groups of approximately equal weights, and then placed in electric brooders. Later they were placed in growing batteries until termination of the experiment. Ova to be fed to the chickens were removed from the culture slides by putting a drop of water on the slides and then wiping the ova off with a small piece of bread. This bread was then force-fed to the chickens used in the test. Each slide was then examined under a compound microscope to determine whether or not all of the ova had been removed. If any ova were found on the slide, a second wiping was made with another piece of bread. One group of 10 chickens received 200 ± 10 embryonated ova which had been cultured in 90

per cent relative humidity for 30 days, and each of 10 chickens in the second group was fed the same number of ova which had been cultured in water for the same length of time. Twenty-one days subsequent to the experimental feeding of the ova, the chickens were sacrificed and the intestine from gizzard to the yolk sac remnant was removed from each chicken and the contents flushed into a glass jar by the hydraulic method of Ackert and Nolf (1929). In addition, in the second, third, and fourth experiments, each intestine was slit open after it had been flushed out, and the mucosa was scraped off and kept in a separate jar. This technique made possible the recovery of any tissue phase larvae that might have been present.

The numbers, lengths, and sex of all worms recovered were recorded. Measurement of the larger worms was accomplished by projecting the image of the worm, enlarged six times, on the ground glass plate of a view camera. A tracing of the enlarged image of the worms was made on tissue paper, then the length of the tracing was measured in millimeters with a milled wheel calibrated to reduce by six times the length of the tracing. Measurement of small worms was performed with the aid of a camera lucida.

RESULTS

The number of days of incubation of the two types of egg cultures and the percentages of eggs in each type of culture reaching a particular stage of development, as well as the mortality percentages, are given in Tables 1 and 2. There was a more rapid development of the ova in the water cultures than in the air cultures. Experiments I and II (Tables 1, 2) show that on the 14th day of incubation, 83.6 and 92.1 per cent, respectively, of the ova in the water cultures had reached the coiled embryo stage and in both experiments these percentages represented nearly maximum development. In contrast, a near maximum of 58.6 and 66.9 per cent of the ova in the air cultures in Experiments I and II had developed to the coiled embryo stage on the 14th and 16th day of incubation, respectively. Similar differences in rate of development of the ova in the two types of cultures are evident on examination of the columns listing percentages of ova reaching the vermiform stage. The various percentages of vermiform and coiled embryo stages reported, particularly those relating to the air cultures, were influenced to some extent by the experimental procedure.

The percentages in Tables 1 and 2 under the column heading "Ruptured ova" are largely extracted from the percentages in the columns titled "Vermiform" and "Coiled embryo." Ruptured ova were seen most frequently in the air cultures. The necessity for wetting each air culture to facilitate accurate study of the development of the ova and the subsequent drying of the cultures before returning them to the humidity jars was conducive to rupturing. In the process of these examinations, those ova which had reached the vermiform and coiled embryo stage were prone to rupture.

The viability of the ova in the two types of cultures can be expressed by the percentage of ova dying in each culture as well as by the comparative percentages of ova in arrested developmental stages. The ova cultured in water were more viable than those cultured in air. At the end of 30 days of

incubation, 0.4 and 0.1 per cent of the ova in the water cultures in Experiments I and II, respectively, were dead; whereas, during the same period of incubation, 6.0 and 4.7 per cent of the ova cultured in air died (Tables 1 and 2). Likewise, more ova in the air cultures died from the 2nd to the 12th day of incubation than did the ova in the water cultures during the same period of incubation. A higher percentage of ova in the air cultures showed arrested development than did the ova in the water cultures, particularly in the early morula, late morula, and vermiform stages (Tables 1, 2).

TABLE 1.—The percentages of ova in the various stages of development at a particular time of incubation. Percentages based upon a count of 1000 ova. Experiment I.

| Ova cultured in 90 per cent relative humidity. | | | | | | | | | | | |
|--|--------|----------|----------|-----------|--------------|-------------|----------|------------|---------------|--------------|----------|
| Days of incubation | 1 cell | 2-4 cell | 5-8 cell | 9-32 cell | Early morula | Late morula | Tad-pole | Vermi-form | Coiled embryo | Ruptured ova | Dead ova |
| 2 | 4.5 | 15.9 | 9.2 | 54.4 | 12.8 | — | — | — | — | — | 1.8 |
| 4 | 0.6 | 8.8 | 2.7 | 6.2 | 22.8 | 18.1 | 36.6 | — | — | — | 2.8 |
| 6 | 0.5 | 5.0 | 3.7 | 4.1 | 17.3 | 14.1 | 22.4 | 28.3 | — | — | 3.2 |
| 8 | 0.5 | 3.5 | 2.6 | 3.2 | 9.9 | 11.5 | 14.3 | 49.2 | — | 0.3 | 3.6 |
| 10 | 0.5 | 2.3 | 2.4 | 2.2 | 8.9 | 8.7 | 8.4 | 59.2 | — | 1.8 | 4.2 |
| 12 | 0.5 | 2.3 | 2.2 | 1.8 | 7.5 | 6.8 | 6.3 | 51.4 | 11.6 | 3.4 | 4.8 |
| 14 | 0.5 | 2.1 | 2.1 | 1.6 | 6.4 | 5.6 | 3.8 | 36.3 | 30.6 | 4.6 | 5.0 |
| 16 | 0.5 | 2.1 | 2.1 | 1.4 | 5.2 | 5.1 | 3.5 | 7.5 | 58.6 | 6.1 | 5.5 |
| 18 | 0.5 | 2.1 | 2.1 | 1.1 | 6.0 | 4.1 | 3.4 | 6.1 | 60.2 | 7.2 | 5.8 |
| 20 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.8 | 3.1 | 5.4 | 60.3 | 8.3 | 6.0 |
| 22 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.6 | 2.7 | 4.9 | 59.8 | 9.9 | 6.0 |
| 24 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.6 | 2.7 | 4.9 | 58.6 | 11.1 | 6.0 |
| 26 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.5 | 2.6 | 5.0 | 57.9 | 11.9 | 6.0 |
| 28 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.5 | 2.6 | 4.7 | 57.6 | 12.5 | 6.0 |
| 30 | 0.5 | 2.1 | 2.1 | 1.1 | 5.9 | 3.5 | 2.6 | 4.7 | 56.6 | 13.5 | 6.0 |
| Ova cultured in water | | | | | | | | | | | |
| 2 | 2.0 | 2.2 | 3.7 | 6.6 | 83.7 | — | — | — | — | — | 0.2 |
| 4 | 0.9 | 1.6 | 1.0 | 1.9 | 3.2 | 11.6 | 78.0 | — | — | — | 0.2 |
| 6 | 0.8 | 1.1 | 0.8 | 2.2 | 2.0 | 3.2 | 3.4 | 84.7 | — | — | 0.2 |
| 8 | 0.8 | 1.1 | 1.0 | 1.9 | 2.0 | 1.2 | 1.8 | 88.6 | — | — | 0.2 |
| 10 | 0.8 | 1.1 | 1.0 | 1.9 | 1.8 | 1.6 | 1.1 | 85.6 | 3.7 | — | 0.4 |
| 12 | 0.8 | 1.1 | 1.0 | 1.9 | 1.8 | 1.2 | 1.3 | 75.4 | 14.0 | — | 0.4 |
| 14 | 0.8 | 1.1 | 1.0 | 1.9 | 1.8 | 1.2 | 1.3 | 5.8 | 83.6 | — | 0.4 |
| 16 | 0.8 | 1.1 | 1.0 | 1.8 | 1.4 | 1.0 | 1.7 | 4.7 | 85.0 | — | 0.4 |
| 18 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.4 | 3.6 | 84.4 | — | 0.4 |
| 20 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.6 | 86.6 | — | 0.4 |
| 22 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.6 | 86.5 | 0.1 | 0.4 |
| 24 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.3 | 86.8 | 0.1 | 0.4 |
| 26 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.3 | 86.8 | 0.1 | 0.4 |
| 28 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.3 | 86.7 | 0.2 | 0.4 |
| 30 | 0.8 | 1.1 | 1.0 | 1.8 | 1.5 | 1.1 | 1.2 | 3.3 | 86.7 | 0.2 | 0.4 |

The criteria for testing the vigor of the infective larvae developing in the two types of cultures were the numbers and the lengths of the worms recovered from the experimental chickens fed embryonated ova from each culture. The results of these experiments are given in Table 3. In all of the experiments, except Experiment II, a larger average number of male and female worms was recovered from the chickens in Group I. However, an analysis of variance of the data yielded an F value which was not significant. The variance of numbers of worms within each group was too large to permit any significance in the differences in numbers of worms between groups. The male and female worms recovered from the chickens in Group I were consid-

TABLE 2.—The percentages of ova in the various stages of development at a particular time of incubation. Percentages based upon a count of 1000 ova. Experiment II.

| Ova cultured in 90 per cent relative humidity | | | | | | | | | | | |
|---|--------|----------|----------|-----------|--------------|-------------|-----------|------------|---------------|--------------|----------|
| Days of incubation | 1 cell | 2-4 cell | 5-8 cell | 9-32 cell | Early morula | Late morula | Tad. pole | Vermi-form | Coiled embryo | Ruptured ova | Dead ova |
| 2 | 5.7 | 12.5 | 9.8 | 61.3 | 8.7 | — | — | — | — | — | 1.5 |
| 4 | 1.7 | 4.7 | 2.4 | 7.3 | 15.1 | 13.8 | 51.8 | — | — | — | 2.7 |
| 6 | 1.2 | 1.9 | 1.7 | 4.5 | 6.4 | 11.3 | 20.5 | 48.5 | — | — | 3.5 |
| 8 | 1.2 | 1.2 | 1.2 | 3.3 | 4.5 | 7.0 | 10.9 | 65.8 | — | — | 4.4 |
| 10 | 1.2 | 0.8 | 1.3 | 3.2 | 3.8 | 5.0 | 10.2 | 69.0 | — | 0.6 | 4.4 |
| 12 | 1.2 | 0.8 | 1.2 | 2.1 | 3.3 | 3.6 | 6.3 | 57.3 | 16.4 | 2.6 | 4.7 |
| 14 | 1.2 | 0.8 | 1.2 | 1.8 | 2.8 | 3.1 | 4.4 | 40.3 | 35.2 | 4.0 | 4.7 |
| 16 | 1.2 | 0.8 | 1.2 | 1.8 | 2.8 | 2.8 | 3.0 | 8.1 | 66.9 | 6.2 | 4.7 |
| 18 | 1.2 | 0.8 | 1.2 | 1.8 | 2.6 | 2.4 | 3.1 | 6.3 | 66.8 | 8.6 | 4.7 |
| 20 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 2.1 | 2.2 | 5.6 | 68.5 | 9.3 | 4.7 |
| 22 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 1.7 | 1.9 | 4.8 | 67.9 | 11.4 | 4.7 |
| 24 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 1.7 | 1.9 | 4.8 | 67.3 | 12.0 | 4.7 |
| 26 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 1.7 | 1.7 | 4.3 | 67.0 | 13.0 | 4.7 |
| 28 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 1.7 | 1.7 | 4.3 | 66.4 | 13.6 | 4.7 |
| 30 | 1.2 | 0.8 | 1.2 | 1.5 | 2.4 | 1.7 | 1.7 | 4.3 | 65.5 | 14.5 | 4.7 |
| Ova cultured in water | | | | | | | | | | | |
| 2 | 0.9 | 1.5 | 2.6 | 93.7 | — | — | — | — | — | — | — |
| 4 | 0.6 | 0.3 | 0.8 | 0.9 | 0.3 | 1.8 | 93.2 | 1.4 | — | — | — |
| 6 | 0.6 | 0.2 | 0.7 | 0.9 | 0.3 | 0.2 | 0.7 | 95.7 | — | — | — |
| 8 | 0.6 | 0.2 | 0.7 | 0.8 | 0.4 | 0.2 | 0.6 | 95.8 | — | — | — |
| 10 | 0.6 | 0.2 | 0.7 | 0.8 | 0.2 | 0.1 | 0.7 | 89.8 | 6.2 | — | — |
| 12 | 0.6 | 0.2 | 0.7 | 0.7 | 0.3 | 0.1 | 0.7 | 57.0 | 39.0 | — | — |
| 14 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 3.9 | 92.1 | — | — |
| 16 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 3.6 | 92.3 | 0.1 | — |
| 18 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 3.4 | 92.5 | 0.1 | — |
| 20 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.5 | 93.3 | 0.2 | — |
| 22 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.3 | 93.5 | 0.2 | — |
| 24 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.2 | 93.4 | 0.4 | — |
| 26 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.2 | 93.1 | 0.7 | — |
| 28 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.2 | 93.1 | 0.7 | 0.1 |
| 30 | 0.6 | 0.2 | 0.7 | 0.6 | 0.4 | 0.1 | 0.7 | 2.2 | 93.1 | 0.7 | 0.1 |

erably longer than the male and female worms recovered from the chickens in Group II (Table 3). An analysis of variance of the differences in the lengths of the worms from the two groups of chickens yielded a highly significant F value (271.0).

In the Experiments II, III, and IV the mucosae were scraped from the intestines of the experimentally infected chickens in order to recover the tissue phase larvae which might have been present. In the three experiments a total of 66 tissue phase larvae were recovered from the chickens fed embryonated ova cultured in water, whereas a total of 11 tissue phase larvae were recovered from the chickens fed ova cultured in air.

The difference in weight gains made by the two groups of chickens was used as the criterion for comparing the virulence of the larvae developing from the two types of cultures. In all of the experiments, except Experiment III, the chickens in Group I gained on the average more than did the chickens in Group II (Table 3). However, when these differences in weight gains were subjected to the analysis of variance they were found not to be significant ($F = 0.62$).

DISCUSSION

The chicken ascarid, *Ascaridia galli*, is used extensively in experimental studies in parasitology. In the present study as well as in many other studies reported by various authors there is an inherent large variation within an experiment in the numbers of worms recovered from chickens given a regulated dose of infective ova. Aside from the various factors of resistance and individual variation in susceptibility of the hosts, it might be hypothesized that the usual method of culturing ova in water could have had some influence on their vigor and virulence. Such a culture medium certainly is unlike the usual barnyard conditions under which the ova develop in nature. The use of a nearly saturated atmosphere in this study was an attempt to approximate more closely the conditions of moisture and oxygen tension associated with the media in which the ova develop in nature. The results of this study indicate an equal vigor of the larvae developing from ova cultured in water and in air when vigor is measured in terms of numbers of worms recovered from experimentally infected chickens. However, when vigor of the worms is measured by rate of growth, those larvae from ova cultured in air appear to be the more vigorous (Table 3). This rapid growth of the larvae from ova cultured in air can be related, perhaps, to a shortening of time spent in the tissue phase since they began their growth at an earlier time than did the larvae developing from ova cultured in water. Tugwell and Ackert (1950) have demonstrated that there is very little growth in size of the larvae while they are in the tissue phase, most rapid growth occurring when the larvae return to the lumen of the intestine. As mentioned in the experimental results, far fewer tissue phase larvae were recovered from those chickens fed ova cultured in air than were recovered from chickens fed ova cultured in water. One cannot preclude the possibility, therefore, that the larvae developing from ova cultured in air may be less constrained to undergo the tissue phase. Todd et al. (ibid) hypothesized from their study on age differences

in virulence of *A. galli* eggs that this worm could mature within its host without partial migration within the intestinal mucosa.

Todd et al. (ibid.) demonstrated a relationship between the age of infective *A. galli* larvae and their virulence. Such virulence was expressed in the failure of the host to gain as much weight when exposed to infective ova which had been cultured 14-21 days as did those hosts exposed to older cultures. When the data on weight gains made by the chickens in the two experimental groups in the present paper were compared, there were no significant differences in the virulence of larvae of similar age reared from ova cultured in water or in air.

TABLE 3.—Weight gains and the numbers, lengths, and sex of worms recovered from chickens fed ova cultured respectively in air and in water. Mean values based upon a total of 459 worms recovered from chickens in Group I and 368 worms recovered from chickens in Group II.

| Experiment | Number of chickens per group | Group I Chickens fed ova cultured in air | | | | Group II Chickens fed ova cultured in water | | | |
|------------|------------------------------|---|--------------------------|-------------------------|---------|--|--------------------------|-------------------------|---------|
| | | Mean weight gains (gm.) | Mean no. worms recovered | Mean worm lengths (mm.) | Females | Mean weight gains (gm.) | Mean no. worms recovered | Mean worm lengths (mm.) | Females |
| I | 10 | 245.1 | 2.1 | 21.8 | 27.6 | 223.9 | 1.1 | 6.7 | 2.8 |
| II | 10 | 242.7 | 1.5 | 24.1 | 30.1 | 221.4 | 4.4 | 13.2 | 12.1 |
| III | 10 | 303.2 | 3.0 | 21.9 | 26.4 | 335.0 | 1.5 | 8.4 | 23.5 |
| IV | 10 | 344.2 | 16.2 | 25.3 | 30.3 | 315.5 | 10.0 | 23.8 | 27.6 |

* Differences between Group I and II significant beyond the 1 per cent level.

SUMMARY

A study was made to ascertain the rate of development, viability, vigor, and virulence of *A. galli* ova cultured in 90 per cent relative humidity and in water kept at 30° C. for a period of 30 days. Four experiments were performed, two of which included a study of the development of 4000 ova at 48-hour intervals. Following the 30-day incubation period of both types of cultures, each culture was fed to Single Comb White Leghorn chickens to determine the vigor and virulence of the infective larvae. The results were as follows:

There was a more rapid development of ova in the water cultures than in the air cultures (90 per cent relative humidity).

There was a larger percentage of viable ova in the water cultures than in the air cultures. At the end of 30 days of incubation in Experiments I and II, 0.4 and 0.1 per cent of the ova, respectively, were dead. During the same period of time in the same experiments, 6.0 and 4.7 per cent of the ova, respectively, died in the air cultures.

There was no significant difference between the number of worms recovered from chickens fed ova cultured in water and ova cultured in air. However, the average length of the worms recovered from the chickens fed ova cultured in air was greater than the average length of worms recovered from chickens fed ova cultured in water. This difference proved to be highly significant when the data were subjected to the analysis of variance.

No differences in the virulence of the larvae from the two types of cultures were detected insofar as there were no significant differences in weight gains made by the chickens fed the two types of egg cultures.

The possibility of a shortening of the time spent in the tissue phase or even the elimination of the tissue phase by a majority of the larvae developing from ova cultured in 90 per cent relative humidity is discussed.

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Studies on North American Fairy Shrimps with the Description of Two New Species

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Over a period of fifteen years the writer has collected field records of anostracan phyllopods, a group of crustaceans commonly called fairy shrimps, which inhabit for the most part temporary pools of fresh water or brine waters of excessive salinity. Intensive studies on the life history and on seasonal and geographical distribution of these organisms made in east central Illinois and northeastern Ohio have already been published and are referred to below. In addition, an attempt has been made to gather all published records, to borrow available museum collections, and to contact field biologists and collectors for specimens of all North American species. It was hoped that enough material could be assembled to map the geographical distribution of the Anostraca inhabiting this continent. This goal has not yet been reached. Insufficient records are known, and too little work has been done on this group to attempt any significant mapping of distribution at this time. Some species have been collected only a few times since their original discovery. Many extensive areas have never been searched for fairy shrimps, and in only a few small areas have intensive surveys been made. A number of locality records, even some state records, have been based upon a single collection of a few specimens. Also, the sporadic and ephemeral nature of the occurrence of these crustaceans make an accurate determination of their distribution extremely difficult. In compiling the data which have come to hand, however, a number of new or rare state and locality records have been uncovered which are worthy of publication in order to extend the known range of certain species and to encourage further collecting of these organisms in North America. New records on the collection of more than one species of fairy shrimp from the same pool have also been discovered, and a careful examination of all specimens available to the writer has disclosed a number of individuals with abnormally developed appendages. In addition to these matters, recent annual surveys of the fairy shrimp populations in east central Illinois are included to furnish more information on the intriguing problem of annual fluctuations of occurrence and abundance of these animals. The writer is indebted to many volunteer field collectors and to a number of museum staff members who kindly sent specimens for study, and to the General Biological Supply House of Chicago for assistance in making contact with field biologists. To all of them my heartiest thanks are given. Those whose contributions are used in this paper are named in connection with each specific reference. Additional material sent to the writer will be gratefully received. New locality records from the state of Ohio have been used in a special series of papers on fairy shrimp studies made in that state. Locality records of the anostracan collection of the United States National Museum have not been used here

in view of the monograph being planned by Dr. Folke Linder on the phyllopod collections of that institution. Recent papers which report distribution records of fairy shrimps in North America include the following: Dexter (1946); Coopey (1946, 1950); Dexter and Kuehnle (1948, 1951); Leonard and Ponder (1949); and Moore (1950, 1951a, 1951b).

REVIEW OF GEOGRAPHIC DISTRIBUTION WITH NEW LOCALITY RECORDS

Polyartemiella hansenii (Murdoch) 1874 has been reported from the coastal plains of Alaska and Yukon Territory within the arctic circle. To this we can now add the Northwest Territories. On July 7, 1945, Dr. R. B. Miller of the University of Alberta collected specimens of this species from rain-water pools along the rocky shores of Great Bear Lake near Port Radium (Plate II, fig. 14).

Thamnocephalus platyurus Packard 1879 has been listed from Kansas, Colorado, Oklahoma, Texas, Arizona, and San Luis Potosi in Mexico. Three new states, Nevada, New Mexico, and California, are now added to the list. In the spring of 1940, Dr. V. M. Tanner of the University of Utah collected a single female specimen at Moapa Valley, Muddy River, in Clark County of Nevada. Dr. G. H. Childs sent from the collection of the American Museum of Natural History two specimens of this species from Chaco Canyon in New Mexico where they were found by G. H. Pepper who collected there in August and September of 1896. Later, Prof. K. S. Buchanan collected specimens on July 4, 1944, from a temporary pond in Curry County, New Mexico, four miles west and three miles north of Clovis (Plate II, fig. 8). One male measured 36 mm. and two females measured 40 mm. Creaser (1935) stated the average size to be 26 mm. Some *T. platyurus* were reared from mud by Dr. R. M. Bond, U. S. Soil Conservation Service, who obtained dried mud from lake bottom near Baker, California, in October of 1931. He also raised a single female from a sample of mud two years of age which had been collected from Newberry, near Barstow, California.

Chirocephalopsis bundyi (Forbes) 1876, which at various times has been placed in the genera *Eubrachipus* and *Pristicephalus*, is known from the following localities: Alaska, Yukon Territory, Alberta, Manitoba, Ontario, Quebec, Massachusetts, New York, Michigan, Wisconsin, Ohio, Indiana, and Wyoming. The only pond in the state of Ohio known to contain a large population of this species is shown in fig. 2 of plate I. Seven new localities are now known: New Hampshire, Vermont, Illinois, Minnesota, South Dakota, Nebraska, and Utah. Also, additional records are listed for Yukon Territory and Manitoba. In the collection of Dr. R. M. Bond there are specimens which were collected from Hanover, New Hampshire, on May 7, 1934, by W. W. Ballard, and by the same collector from Norwich, Vermont, in May of 1934. Dr. H. B. Hitchcock of Middlebury College obtained specimens from a flood plain meadow near Middlebury, Vermont, on April 18, 1945. He had also collected there the preceding year, although specimens were not saved, and he had observed fairy shrimps in other nearby pools along Otter Creek. In 1949 he failed to find any fairy shrimps in the pools along Otter Creek flood plain, but in April and May, 1950, he collected

many specimens of *C. bundyi* from two ponds and a drainage ditch in the same locality. One of these pools was the same as the one from which his 1945 collection was made. Dr. Hitchcock has not found fairy shrimps in any other section of this region. In a restudy of the fairy shrimps of pond 9 north of Urbana, Illinois, on March 24, 1948, the writer found two specimens of *C. bundyi* mixed in with a large population of *Eubbranchipus serratus*. The following year *C. bundyi* was not found in this pond, but a single specimen was collected in pond 8 a few rods away, among a large sample of *E. serratus* collected on March 22 (Plate I, figs. 6 and 7). *C. bundyi* was not found in either pond when sampled in 1950. Dr. Samuel Eddy of the University of Minnesota collected *C. bundyi* from a pond near the St. Paul Water Supply in Minnesota on May 15, 1931, and again in a pond north of the Farm School at St. Paul on May 25, 1932. Dr. J. B. Gerberich, Duluth Branch of the University of Minnesota, collected the same species from a temporary pool at Chester Park in Duluth between May 1 and 22, 1948. On May 30 no specimens could be found in the pool. Additional specimens were collected from three temporary pools at Duluth between April 9 (metanauplii) and May 22, 1949, by S. M. Cox. Dr. Geberich and William MacGregor re-collected from the Chester Park pool on May 3, 1950 and 1951. Mr. H. E. Thurston, Washington High School at Sioux Falls, South Dakota, sent a collection of fairy shrimps in April of 1948 which had been found in small pools in the Granite Falls area of the city. Unfortunately all of the specimens were females, but, as nearly as could be determined, they were probably *C. bundyi*. Dr. R. E. Hill and his associate Dr. M. H. Muma of the Nebraska Agricultural Experiment Station collected specimens of *C. bundyi* from one temporary pool at Norfolk and another one at Beemer, Nebraska, on April 20, 1949. Specimens were found again at the Beemer pool on May 7. A collection of female fairy shrimp which are probably of this same species were collected from a pond at Fremont by J. W. Lomax on April 15, 1948, and again by Drs. Hill and Muma on April 30 near Grafton, Nebraska. Dr. Stanley Mulaik, University of Utah, sent two specimens from a lot collected at Paradise Park in Ashley National Forest located in the Uinta Mountains of Utah. They were collected on June 28, 1948, by Dr. D. M. Rees and Mr. Louis Nielsen from grassy woodland pools at an elevation of 10,300 ft. and were reported as being plentiful in the pool. The only published records of *C. bundyi* from the Province of Manitoba known to the writer are mentioned incidentally in a study devoted primarily to mollusks inhabiting temporary pools. Mozley (1928, 1932) listed *Eubbranchipus gelidus*, a synonym of *C. bundyi*, from vernal pools in the Municipality of St. Vital and in a temporary pond near Winnipeg, Manitoba. Because of the paucity of records from this province, several more recent ones are given here. Prof. I. G. Arnason, University of Manitoba, sent a record of this species (specimens not seen by the writer) collected at Winnipeg. Date of collection was not given, but it was probably in 1945 or 1946. Specimens collected from Churchill, Manitoba, on July 22, 1947, by Major Brian Hocking of the University of Alberta were sent to the writer by Dr. R. B. Miller. Additional material from Churchill collected between July 4 and July 12, 1950, was obtained by

Dr. A. S. West, Queens University, Ontario. He collected his specimens from several temporary tundra and transitional pools and one permanent but rapidly diminishing pond where they were common but scattered in distribution. Collections were also made from woods pools ten miles south of Churchill near Warkworth Creek on June 28, 1950. Collections of *C. bundyi* were also received from Dr. C. R. Twinn, Division of Entomology, Canada Department of Agriculture, that were made near Whitehorse in Yukon Territory. On May 5, 1950, L. C. Curtis and W. R. Richards collected specimens from a temporary pool in a willow swamp. On June 11, 1950, W. R. Richards and R. Hasselback collected specimens at the same place.

Eubrachipus vernalis (Verrill) 1869 has been recorded from Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, and Ontario. New records include West Virginia, Tennessee, and North Carolina. Mr. L. W. Wilson, Moorefield High School, collected this species for three years, 1944-46 inclusive, near Moorefield, West Virginia. After intensive field collecting throughout Hardy County for a number of years, he obtained the following records. From January 28 to April 1, 1944, he found *E. vernalis* abundantly in four bodies of water at Kuykendall's Island. Three of these were shallow temporary pools, and one was a pond which does not usually dry out completely but does have a dry margin during the summer season. No fairy shrimps were present in three nearby permanent ponds, and none of these seven pools and ponds contained specimens in 1943 or 1945. Repeated visits were made to them during February, March, and April of 1945, but at no time could fairy shrimps be found in the pools where they had been so abundant the preceding year. However, two new records were found that season. A temporary pool in Moorefield yielded several specimens on February 6 and 27. On January 9, 1946, metanauplii and partially grown fairy shrimp were again collected there. The second discovery of 1945 was a permanent pond three to four miles north of Moorefield which also contained *E. vernalis* that spring and again in March of 1946. This is known as Leatherman's Pond, and like other permanent ponds inhabited by fairy shrimps, it has a dry margin in summer time, permitting the shrimp eggs to dry just as effectively as if the entire pool evaporated during the summer season. In addition to the preceding two ponds, four other bodies of water were found inhabited in the season of 1946. Two of these were additional temporary pools near the others in Moorefield where immature specimens were collected on January 6 and 9 (Plate II, figs. 11 and 12). Several other pools nearby were not inhabited. Another collection was made at Cunningham Station on February 28, and one at Paskell's Hill in Moorefield on March 5, 1946. It was reliably reported to Mr. Wilson that fairy shrimps were also present in the last mentioned pool during the late winter of 1943 and 1944. This same species was collected March 13 and April 16, 1946, from a pool at Athens, West Virginia, at an elevation of 2600 ft. by Dr. E. M. McNeill, Concord College. He found them in great abundance, and at the same time several specimens from Princeton, West Virginia, were brought to the class room of Mrs. McNeill who was teaching in that community.

Specimens of *E. vernalis* collected from a shallow pool in Knoxville, Tennessee, on February 23, 1946, were sent by K. S. Buchanan when she was at the University of Tennessee. The same species was collected by Dr. Tom Daggy, Davidson College, from two temporary meadow pools on the Rocky River flood plain in Cabarrus County, North Carolina, on February 23 and March 2, 1951. In one of the pools it was found again on February 1, 1952, but was neither in the second one, from which only two females had been collected the previous year, nor in seven other nearby pools. Dr. E. E. Brown, also at Davidson College, had previously examined these same two pools over a number of years without finding fairy shrimps. In the collection of the Museum of Comparative Zoology at Cambridge there are specimens of *E. vernalis* which probably represent the first collected in Rhode Island, but which had never been reported. They were collected from a goldfish pond at Newport on March 1, 1877, by S. Powel. The first published record for the state and the only one known to the writer was reported by Williams (1907). Typical habitats of this species are illustrated in Plate I, figs. 1 and 3.

Eubbranchipus serratus Forbes 1876 has been found in Wisconsin, Illinois, Missouri, Nebraska, Kansas, Oklahoma, and Oregon. Indiana, Montana, and Washington are now added to the list. Rev. J. W. Baechle of St. Joseph's College collected in the spring of 1945 from a swamp pond on the campus of that institution, one mile south of Rensselaer, Indiana, abundant specimens of *E. serratus*. This represents the eastern-most record of the species. Dr. R. M. Bond collected the same species from Lower Flathead Valley, 25 miles north of Missouri Valley, in Montana, on April 20, 1937. Dr. R. H. Whitaker and C. W. Fairbanks formerly at the State College of Washington collected *E. serratus* from Rock Pond on April 30, 1949, near Ewan in the northwest portion of Whitman County, Washington. The depth of this pond is less than a meter throughout, but it dries out completely only during exceptionally dry summers. Two of the ponds from which Leonard and Ponder (1949) recently recorded *E. serratus* for the first time from Kansas are shown as figs. 9 and 10 of Plate II.

Eubbranchipus holmani (Ryder) 1879 has been reported from Connecticut, New York, New Jersey, Virginia, Ohio, Tennessee, and Louisiana. Only a few specimens have ever been collected, many of them have been lost, and for some time the status of the species was in dispute. Most of the records have been published under names now regarded as synonyms. For these reasons several records are reported here from the previously known localities. In the collection of Dr. R. M. Bond there are a few dozen specimens collected on May 20, 1932, from New Haven, Connecticut. Additional specimens from that state have been collected by Dr. D. Richardson of Connecticut College. Among abundant specimens of *E. vernalis* she collected on March 22, 1949, from a roadside pool near New London were five specimens of *E. holmani*. In April of 1950 she sent a sample of living specimens of which 17 were received in good condition. All of these were *E. holmani*. Fairy shrimps have been collected from this pool every year by members of her department for the past 12 or 15 years, and it is the only pond known to contain fairy shrimps in that region. Dr. E. P. Creaser collected four specimens of *E.*

holmani with a large sample of *E. vernalis* on April 20, 1947, on Long Island. Two new state records (Georgia and North Carolina) are added at this time. Drs. R. E. Bellamy and G. J. Schumacher at the Emory University Field Station in Newton, Georgia, sent specimens collected from two ponds in Baker County, Georgia. On January 8 and 18, 1951, a total of 19 *E. holmani* were collected from Springfield Pond while on January 9 and 30, 1951, 14 specimens of this species were taken from Putney Pond. Earlier, some immature specimens had been collected on December 18, 1950, but could not be determined accurately until fully mature ones were obtained. A single male of *E. holmani* was collected from a pool inhabited by *E. vernalis* on the flood plain of Rocky River in Cabarrus County, North Carolina, on February 23 and March 2, 1951, and again on February 1, 1952, by Dr. Tom Daggy.

Eubbranchipus ornatus Holmes 1910 has been known from Wisconsin, Minnesota, and Manitoba. Three new states can now be added. The collection of Dr. R. M. Bond adds North Dakota and Montana to the list. Specimens without data were collected from Devils Lake in North Dakota, and also from the Blackfoot Reservation near Babb, Montana, on April 17, 1937. Dr. R. E. Hill sent a single specimen of this species collected by a colleague, J. W. Lomax, on April 14, 1950, near Wisner, Nebraska. This was collected from a shallow puddle near a flooded culvert which overflowed during a heavy rainstorm. Such rarities existing under precarious conditions emphasize the sporadic nature of these crustaceans.

Eubbranchipus oregonus Creaser 1930 has been collected in Oklahoma, Oregon, and British Columbia. A new record from the state of Washington was made by L. A. Peters who collected specimens from the Upper Farm of the County Club at Bainbridge Island on March 18, 1937. Because of the rarity of this species it is interesting to note several other records which have come to hand even though they are not the first to be published from their respective localities. Dr. R. M. Bond, who sent the specimens for the preceding record, collected specimens in a pool 10 miles west of The Dalles, Oregon, on the Columbia River Highway, not far from the type locality (Portland) on March 27, 1937. Dr. Paul H. D. Parizeau collected *E. oregonus* from a temporary pond at Victoria in British Columbia on April 23, 1945. The earliest date on which he has collected specimens from that pool is January 17 (Plate II, fig. 1). This is the second record published from that province. He also knew of at least six records of this species from pools within a radius of 10 miles of Victoria.

Branchinella lithaca (Creaser) 1940 has not been reported since it was first described from rain pools on the summit of Stone Mountain in De Kalb County, Georgia (Creaser, 1940). Specimens of this species were collected from the type locality in July, 1951, by Dr. R. B. Platt, Emory University.

Artemia salina (L.) 1851, a cosmopolitan species and the only salt-water species of the Anostraca in North America, has been found in the western hemisphere in salt-water lakes and evaporating basins from San Domingo, Connecticut, Utah, Washington, Oregon, California, and Lower California. The island of Puerto Rico and the states of Nevada and North Dakota are now added to the list. The writer has received specimens from Dr. N. T.

Mattox of the College of Agriculture and Mechanic Arts at Mayaguez, P. R., that he collected in abundance from salt evaporation ponds at the following localities: Ensenada Salinas, June 1947; Salinas de Papaya near Parguera, September 1947; Salinas de Cabo Rojo, March 20, 1948 (from 3 ponds); and Boqueron Salinas, August 27, 1949. In the phyllopod collection of Dr. Mattox there are specimens of *A. salina* obtained between Falcon and Hazen, Nevada, on May 19, 1940, by Dr. Ira La Rivers. Prof. G. C. Wheeler, University of North Dakota, sent to the U. S. National Museum one male and one immature female *A. salina* taken from a brackish pool at Crystal Springs in Kidder County, N. Dak., on October 31, 1949. The collection of Dr. R. M. Bond contains an interesting lot of specimens collected about 1890 by A. E. Verrill from a fire barrel on a bridge in New Haven, Connecticut. While this locality is not new, the habitat is of unusual interest.

Branchinecta paludosa (O. F. Muller) 1788 is widely distributed throughout high northern latitudes around the world. Records from the following regions in the western hemispheres are known: Pribilof Islands, Alaska, Yukon Territory, coastal plains of the Arctic Ocean and Canadian Archipelago in general, Baffin Island, Greenland, Labrador, Quebec, Manitoba, and Wyoming. The American Museum of Natural History has ten specimens, not seen by the writer, labelled "Taylor Harbor, Nova Scotia" (Taylor Head?—R. W. D.) and were received at the museum on December 10, 1928. Nothing else is known about them. This is the most southerly record for the species in North America, except for the singular record of Linder (1941) from Medicine Bow Mountains in Wyoming, at an elevation of 9,700 feet.

Branchinecta shantzi Mackin 1952 has been reported from Oklahoma, Wyoming, Colorado, California, and Oregon. This species has long been known as *B. coloradensis* Packard 1874. Mackin (1952) has recently shown that by error Packard had applied the name to a different species, so that his new species was actually without a valid name until Mackin proposed *B. shantzi* for the one Packard had in mind, and which he later (1883) described accurately but under the wrong name. Plate II, fig. 16, shows a typical alpine habitat of this species. Linder (1941) thought that the name *B. lindahli* (Packard 1883) as used in the past and which Mackin has changed to *B. coloradensis* is a synonym of the above species and may represent immature stages or a variety of *B. shantzi* (i.e. the former *B. coloradensis*). *B. coloradensis* has been reported under the name of *B. lindahli* from Iowa, Kansas, Nebraska, North Dakota, and Wyoming. Under the corrected name of *B. coloradensis* it has been recorded from Colorado and New Mexico. The fact that it has been thus far reported from six states from which *B. shantzi* has not been found, and especially the fact that the writer and others have observed mature specimens with distinctive characters, indicate that it is a separate species which now carries the name of *B. coloradensis* but not for the reason given by Linder (ibid.). The state of Utah is now added to the range of *B. shantzi*. Dr. V. M. Tanner collected this species from Washington Lake in the Uinta Mts. of Utah at an elevation of 10,500 feet on July 24, 1930, and again at Mirror Lake, also in the Uintas, in August of 1930, at an elevation of 10,300 feet.

Arizona and Nevada are now added to the range of *B. coloradensis*. Dr. R. M. Bond collected specimens from a sheep pool between Tuba City and Tonalea, Arizona, on September 26, 1931, and raised one out of the mud taken from the same place. It was reared in January of 1933. Dr. La Rivers sent specimens of *B. coloradensis* collected four miles south of Indian Springs in Clark County, Nevada, in 1941 by A. W. Vanderhorst. The same person found this species in two pools near camp cabins in Valley-of-Fire State Park, also in Clark County, on January 17, 1942. Small but fully mature specimens were collected by Dr. La Rivers and T. J. Trelease from a small muddy roadside pool on Marble Butte, Pyramid Lake in Washoe County, Nevada.

Branchinecta lindahli Packard 1883 has been most commonly known as *B. packardii* Pearse 1912 until the revision of this group by Mackin (1952). This species has been thus far reported from Colorado, Oklahoma, Texas, Wyoming, and Kansas. Records from Nebraska, New Mexico, and Arizona now extend the range. Drs. M. H. Muma and R. E. Hill collected *B. lindahli* from a temporary pool at Minden, Nebraska, on May 13, 1949. Specimens in the collection of the American Museum of Natural History collected by G. H. Pepper in August-September of 1896 were found at Chaco Canyon, New Mexico. Determination of species was made by Dr. W. G. Van Name. On October 2, 1945, Dr. H. F. Strohecker, then of the New Mexico Highlands University, collected a few specimens (1 male; 3 females) of this species in a rock pool, 10 miles east of Las Vegas. This pool contained only a few gallons of water. The writer has hatched many specimens of *B. lindahli* over a period of several years from mud collected in 1945 near Clovis, New Mexico, by K. S. Buchanan. Details will be given at a later date. In November of 1947, Mr. L. J. Hendricks also sent to the writer a sample of dried mud taken from a sink hole at Hobbs, New Mexico. On December 20, 1947, this was soaked in tap water and seven days later a specimen of *B. lindahli* was discovered in the aquarium. Specimens of this species were collected by Dr. R. M. Bond from a rock pool between Begashebito and Shonto, Arizona, on September 27, 1931.

Branchinecta gigas Lynch 1937 has been reported from the states of Washington and Montana only. Nevada and Utah are now added. The Museum of Comparative Zoology has a male and a female specimen measuring 6.75 cm. and 12.6 cm. respectively, collected from Alkali Lake, 16 miles north of Reno, Nevada, by Peter Frandsen and son. It was received at the museum on July 16, 1914, and kindly loaned to the writer through the courtesy of Dr. Elizabeth Deichmann. Dr. Ira La Rivers sent a male specimen of *B. gigas* which measured 5.5 cm. in total length. It was collected May 12, 1941, from Dry Lake in Lawton Valley, 15 miles northwest of Reno. Specimens have usually been found every spring that this lake has been examined. Other specimens of this species collected in the vicinity of Reno in 1941 dried out in storage during the absence of Dr. La Rivers. Five specimens were collected by Dr. V. M. Tanner, 10 miles west of Hinkley in Millard County, Utah, on April 19, 1930. They measured 34, 38, 42, 46, and 50 mm. respectively, with an average total length of 42 mm.

Streptocephalus texanus Packard 1871 has been known to occur in Nebras-

ka, Kansas, Colorado, Oklahoma, Texas, New Mexico, Arizona, Utah, California, and San Luis Potosi, Mexico. Specimens were collected from San Luis Potosi in central Mexico on August 6 and 10, 1878, by Edward Palmer, and are in the collection of the Museum of Comparative Zoology. Recently collections from the vicinity of Gainesville, Florida, have come to hand containing this species. The whole matter of Floridian records is discussed in detail below. A second record for the state of California was made by Dean Douglas Whitaker of Stanford University who collected this species on July 10, 1949, from a small pond in the Sierra Nevada Mountains at an elevation of 8005 feet. Here the shrimps were present in great abundance. This site, in the watershed between the Mokelumne and Stanislaus Rivers and known locally as Pacific Pass, is only some 40 miles southeast of the first locality reported for this species in California by Creaser (1930b).

Streptocephalus seali Ryder 1879 has been known from New Jersey, Virginia, Illinois, Minnesota, South Carolina, Florida, Alabama, Mississippi, Louisiana, Texas, Oklahoma, Kansas, Colorado, Arizona, Vera Cruz (Mexico), Oregon, and Alberta. The record from South Carolina rests upon a single specimen. Only one collection has thus far been reported from Alabama and Mississippi. A second record from Alabama is given here. Specimens were collected at Silver Hill in Baldwin County, Alabama, by George Nelson in July of 1945. They were sent to the writer from the Museum of Comparative Zoology by Dr. Elizabeth Deichmann. The second record for Illinois was made by Dr. W. M. Gersbacher who sent a collection of *Eubrachhipus vernalis* and *S. seali* taken from three pasture pools at Carbondale in March, 1948. Only one male and one female of the latter species were obtained. These are the only ones known from Illinois since first found there by Dr. Van Cleave (1928). Dr. Gersbacher did not find any fairy shrimps in the Carbondale ponds in 1946 or 1947. Only a few were collected in 1948, but many specimens were collected the following year, although *S. seali* was not present in the material examined by the writer. In December of that year and the first four months of 1950, Mr. J. D. Parsons, studying under Dr. Gersbacher, collected periodically from these same pasture pools, and while a large amount of material was sent to the writer, *E. vernalis* was the only species encountered. *S. seali* generally lives in temporary pools of low elevations. Dr. R. W. Pennak, University of Colorado, has sent a record from a permanent pond in high elevation near Boulder (Plate II, fig. 17). Specimens of unusual size were sent to the writer by Dr. J. E. Moore, University of Alberta. The largest were a male of 35 mm. and a female of 37 mm. collected near Taber, Alberta, on July 19, 1951. Additional shrimps of unusual size were obtained from other prairie pools of southern Alberta at Calgary on July 28 and at Foremost on August 11, 1951. Nebraska and North Dakota are now added new to the list of states containing this species. J. W. Lomax found it living in a ditch at Kilgore, Nebraska, on May 17, 1949, and Dr. R. L. Post collected specimens from a slough near Fargo, North Dakota, on June 18, 1951. Dickinson (1948) has given the first definite account of *S. seali* from Florida based on specimens he collected near Gainesville. Identification was made by the writer. Because of confusion regarding

the occurrence of fairy shrimps in that state and the acquisition of some very important collections made by zoologists at the University of Florida, the whole subject will be reviewed here with the description of two new species from that state.

RECORDS OF ANOSTRACA FROM FLORIDA

Packard (1880) described a species he thought new as *Streptocephalus floridanus* which had been collected in Florida. This is apparently the first published account of Anostraca from that state. In his monograph Packard (1883) wrote of this species, "A pair, male and female, found in the St. Johns River, Florida, May 23, 1879, by Alex P. Fries; received from Dr. Carl F. Gissler." This statement was quoted by Daday (1910) who recognized the species in his monograph. Pearse (1918), however, questioned its validity with the statement that "Packard described another species, *S. floridanus*, but the description was not definite enough to differentiate it from other American species." Creaser (1930b) reduced it to synonymy under *S. seali* with the explanation that Packard had described immature specimens of this species. At least there was a record of a fairy shrimp from Florida, although Creaser (ibid.) did not include it on his map of distribution of *S. seali*. He wrote, "A locality record for this species in Florida is omitted on the map because of inadequate data." Another early record of a fairy shrimp from Florida has been discovered, but unfortunately it too is very indefinite. In the phyllopod collection of the Museum of Comparative Zoology there is a single female specimen which is probably a member of the genus *Streptocephalus*. The label reads "Mrs. Willard. Near Poroelton, Fla." No date was given, but indications are that it is an old specimen. All efforts to locate a place name of Poroelton in Florida have failed. Thus the occurrence of Anostraca in that state remained very obscure until recent collections were made by Drs. H. H. Hobbs, I. J. Cantrall, and J. C. Dickinson while they were at the University of Florida. Between 1938 and 1947 these three zoologists, with a number of student assistants, collected an abundance of Anostraca from temporary pools in the Gainesville area. Dickinson (1948) has published records of *Streptocephalus seali* taken in his own study. Additional records from the University of Florida collections are as follows. Several *S. seali*, with four specimens of *S. texanus*, were collected from a temporary pond in low woods of Florida Caverns State Park at Marianna on July 15, 1942, by L. Giovannoli. *S. seali* was collected by Hart Achenback and Dr. Hobbs on March 23, 1946, from a small cypress pond eleven miles southeast of San Mateo (Flagler Co.) on State Highway 28. The above specimens are in the Hobbs' collection in addition to several lots of *S. seali*, with a few *S. texanus* mixed in, obtained in the Gainesville area in 1941 and 1942. The Cantrall collection is worthy of note because of the very large specimens obtained. Three males collected by W. M. McLane, L. J. Carr, and W. M. Beck in the fall of 1938 some 6-10 miles southwest of Gainesville measured 36, 39, and 40 mm. respectively. Creaser (1930b) refers to a specimen of *S. seali* collected in Oklahoma by Dr. J. G. Mackin measuring 36.2 mm. as being the largest one that had come to his attention. Recently, Moore (1951b) has established a size record of 42 mm. with a specimen collected in Louisiana. Among the

specimens sent to the writer by Dr. Hobbs and Dr. Cantrall were found two undescribed species which are described below as new.

Family CHIROCEPHALIDAE

Eubbranchipus floridanus n. sp.

Male (Plate III, figs. 18-21): Total body length, including cercopods, 5.6 mm. First antennae 1.2 mm. Second antennae 1.8 mm., consisting of two articles of about equal length. Basal article has a slender finger-like process on medial surface at about the mid-point. Distal article is bent at almost right angles. Antennal appendages of 1.8 mm. length arise from base of second antennae and reach beyond extremity of second antennae because of bend in that appendage. Antennal appendages are narrowly elliptical with margins studded with papillae containing spines. Greatest diameter of stalked eye 0.4 mm. Penes 0.8 mm. in length, and have two curved spines at the base which nearly meet at their tips. There are 7 post-genital segments. Cercopods 0.5 mm., gently tapering with long setae of equal length and distribution. Swimming appendages similar throughout, with two propepodites and one epipodite.

Female (Plate II, figs. 22-23). Total length 7.7-8.5 mm. including cercopods. First antennae 1.0 mm. Second antennae 0.5 mm. in length, swollen, with a seta near the distal end and a slight process in middle of front margin. No antennal appendage present. Greatest diameter of stalked eye 0.3 mm. Ovisac nearly circular with diameter of 1.4 mm. and a triangular tip at posterior extremity. There are 7 postgenital segments. Cercopods 0.6 mm., gently tapering with long setae evenly distributed. Thoracic swimming appendages like male.

Remarks: A total of 108 males and 75 females of this new species was found in a mixed collection of *Streptocephalus seali* and *S. texanus* made by Dr. H. H. Hobbs and L. J. Marchand from a temporary pool four miles south of Gainesville in Alachua County, Florida, on March 7, 1939. The majority of the fairy shrimps were *S. seali*, but the new species was easily detected because of its much smaller size and distinctive characteristics. The egg sacs on female *E. floridanus* were well developed whereas they were incompletely developed on many females of *Streptocephalus*. This would indicate that *E. floridanus* matures earlier. This new species would not be confused with any other known species of *Eubbranchipus* because of its small size, unique second antennae and antennal appendages, and the lack of a process on the distal article of the male second antennae. Perhaps *E. oregonus* is most closely related to this since it has the shortest process of the other known species, but its antennal appendages are much shorter and relatively wider, and have coarse serration on their margins.

This new species is named for the state of Florida in which it was found. The male holotype and female allotype have been deposited in the U. S. National Museum (Nos. 93535; 93536). Paratypes (No. 93537) have been divided among that institution, Dr. H. H. Hobbs, and the writer.

Family THAMNOCEPHALIDAE

Branchinella alachua n. sp.

Male (Plate III, figs. 24-28): Total length, including cercopods, 6.7 mm. First antennae 0.7 mm. Second antennae sickle shaped, consisting of two articles. Basal article 0.7 mm. Terminal article 1.1 mm., and has three rows of very fine teeth pointed toward proximal end on concaved edge. Frontal appendage arises from middle of forehead and divides into two branches. Each branch has three terminal branches; an outer filamentous branch 1.2 mm. long with spines along entire length; an inner laminate branch 0.8 mm. long with six pairs of finger-like projections, each ending with a spine, along edges; and a median club-shaped branch with a short stalk and greatest diameter of 0.5 mm. It is covered with minute papillae bearing fine spines. Outstretched frontal organ

about 2.4 mm. Greatest diameter of stalked eyes 0.5 mm. Penes mitten-shaped, curved toward each other and nearly meeting in mid-ventral line. Total length of penes 0.4 mm. Seven post-genital segments. Cercopods 1.4 mm. long, tapered, very slightly curved inwards, and covered with long, fine setae uniformly distributed. Swimming appendages all similar with a single proopipodite.

Remarks: This new species was found in a collection of fairy shrimps made by Dr. I. J. Cantrall from a temporary pond (barrow pit) in Alachua County, Florida, on July 6, 1947. Most of the specimens were *Streptocephalus seali*, but 11 were noticeably different and proved to be an undescribed species. Only males of this species were found. It is unlikely that females of a different genus would be unseparable from the females of *S. seali*. *B. alachua* resembles and undoubtedly is closely related to *B. lithaca* (Creaser) originally described as *Chirocephalus lithacus* (Creaser, 1940). However, *B. alachua* has three rather than two terminal branches at the end of the frontal appendage. This species has been named after Alachua County in which it was found. This is the second species of the genus *Branchinella* to be found in North America. The male holotype has been deposited in the U. S. National Museum (No. 93538); paratypes have been divided among that institution (No. 93539), Dr. I. J. Cantrall, and the writer.

NEW RECORDS OF MULTIPLE SPECIES OF ANOSTRACA LIVING TOGETHER

It has been the experience of most collectors to find but a single species of Anostraca inhabiting any one pool or pond. Exceptions have occasionally been found and have been reported in the literature. In the course of this study several other cases have come to light which are described here.

The record of *Chirocephalus bundyi* being found in Illinois for the first time as reported earlier in this paper was made from two ponds each containing a large population of *Eubranchipus serratus*. Only two specimens of *C. bundyi* were found in one collection and a single one in the other. The situation parallels that of finding a few specimens of *C. bundyi* with *E. vernalis* in 1942, 1945, and 1948 in two nearby ponds of northeastern Ohio (Dexter, 1943; Dexter and Kuehnle, 1948, 1951).

C. bundyi and *Streptocephalus seali* were collected together by Dr. Samuel Eddy from a pond north of the Farm School at St. Paul, Minnesota, on May 25, 1932. The same two species were found together in a prairie pond at Compeer, Alberta, on June 22, 1951, by Prof. J. E. Moore. A collection of Anostraca made by L. C. Bragg from Widdow Lake near Fort Collins, Colorado, on June 12, 1911, contained 66 specimens of *S. seali* and two of *S. texanus*. This record was contributed by Dr. Folke Linder who discovered it while working over the collections of the U. S. National Museum. These same two species were found together in two collections made by Dr. H. H. Hobbs, Jr., in ponds near Gainesville, Florida. The two new species described in this paper were both found among collections of other species—with *S. seali* in one case and a mixed collection of this species and *S. texanus* in the other. Dr. W. G. Moore has also found *S. seali* and *S. texanus* inhabiting the same pond in Louisiana, but he has raised a point (personal communication) regarding such interpretations. Immature specimens of *S. seali* bear features very similar to adult characters of *S. texanus*. Hence only fully mature

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specimens can be determined with accuracy. Creaser (1930b) never found *S. seali* and *S. texanus* together in ponds studied by him.

In a small sample of Anostraca collected by Dr. T. F. Andrews, Kansas State Teachers College at Emporia, from a roadside pasture pond in Gray County on July 4, 1950, two species were found together. There were two male *S. texanus* with one male and one female *Thamnocephalus platyurus*.

As mentioned in an earlier section, two specimens of *S. seali* were collected with a small number of *E. vernalis* by Dr. W. M. Gersbacher at Carbondale, Illinois, in March 1948.

From a sample of mud collected in the basin of a dried-out lake near Clovis, New Mexico, in the summer of 1945 by Prof. K. S. Buchanan and sent to the writer, three species of Anostraca have been hatched at various times between 1946-1951 inclusive. These are *S. texanus*, *B. lindahli*, and *T. platyurus*. Details of these experiments will be given in a later paper. In another case, *S. texanus* was collected from a sinkhole thirteen miles west of Hobbs, New Mexico, on October 5, 1947, by L. J. Hendricks. Three weeks later, after this sinkhole had dried out, he collected some mud from the basin which he sent to the writer. From this, one specimen of *Branchinecta lindahli* was hatched by soaking the dried mud in tap water.

With a group of six specimens of *Thamnocephalus platyurus*, a single male of an undescribed species of *Streptocephalus* was found. The material was collected from a pool fifteen miles west of Ozona, Texas, on August 9, 1934, by Charles E. Burt. This was discovered by Dr. Linder in the collections of the U. S. National Museum. Also from that institution, Dr. Fenner Chace sent a lot of fairy shrimps collected by Dr. E. P. Creaser on April 20, 1947, from Suffolk County Pond six miles northwest of Patchogue on Long Island, New York. Among numerous specimens of *E. vernalis* were found specimens of *E. holmani*. Dr. Dorothy Richardson also collected these two species together at New London, Connecticut, as did Dr. Tom Daggy from Cabarrus County, North Carolina, as mentioned earlier. It is interesting that these two species have been found in a mixed population on several occasions in widely separated areas. Dexter and Kuehnle (1948) reported the two together in Ohio.

As more collecting is carried out and with larger samples obtained than is often the case, additional records of more than a single species in a pond will undoubtedly come to light. Probably such occurrences are not nearly so uncommon as has been thought up to the present time.

RECORDS OF ANOMALOUS APPENDAGES

During the examination of hundreds of fairy shrimps in connection with this study, several were found which possessed abnormally developed appendages. A specimen of *Eubranchipus vernalis* from the Museum of Comparative Zoology collected by C. F. Gissler at Maspeth, Long Island, (received at the museum in 1881) was white in color when collected, according to the label, and has a sharp spine or "tooth" on the right clasper (second antenna) located one-half the distance between the process of the apical segment of the clasper and its distal end. The spine is one-half the length of the process (Plate III, fig. 29). Two specimens of this same species collected by the

writer from pond P88 near Brimfield, Ohio, on March 16, 1947, have an abnormally developed antennal appendage. One specimen is an immature male and the other an immature female. The presence of an antennal appendage on a female is in itself an anomaly. In both cases the right side of the head contains an elongated stalk with an expanded papillated head at its extremity. No such appendage developed on the left side of either specimen (Plate III, fig. 30). On January 22, 1950, a larval fairy shrimp collected from the same pond was observed to have an abnormal extension on the head which possibly would have developed into the same kind of a growth (Plate III, fig. 31). Dr. W. G. Moore, Loyola University, sent a specimen of *Streptocephalus seali* which was found to have a small growth on the right cercopod (Plate III, fig. 32).

Among specimens of *E. serratus* taken by the writer at Savoy, Illinois, on March 21, 1946, one male specimen was discovered in which the antennal appendage and the second antenna on the right side were absent. Gissler (1883) described a male and a female *E. vernalis* in which the left second antenna on both had failed to develop. He interpreted these as malformations in development. In a collection of *E. serratus* made by Rev. J. W. Baechle from a swamp pond on the campus of St. Joseph's College at Collegeville, Indiana, in the spring of 1945, five individuals were found with abnormal appendages. All of them are immature specimens about one-half grown, and four of the five are partial gynandromorphs. One male lacks the antennal appendage on the right side, while another lacks it on the left side and the left second antenna is that of a female specimen. One female has a male antennal appendage on the left side. Another female has a male second antenna on the left side, but no antennal appendage is present. In still another female the left side has both a male second antenna and an antennal appendage. None of the above shows any indication of having a division in the primary sex characters, and thus they are not functionally hermaphrodites. In studying the phyllopod collection of the Museum of Comparative Zoology, the writer uncovered the hermaphroditic specimen of *E. vernalis* described by Gissler (1881) which has a male second antenna on the right, a female antenna on the left, and in addition contains both sex organs.

It will be noted that many of the cases of anomalies reported here are asymmetrical. Had they been otherwise one might suspect a new species had been found. Care should be exercised in a group so susceptible to abnormally developed structures that new species are not described on such a basis.

ANNUAL FLUCTUATIONS OF FAIRY SHRIMP POPULATIONS IN EAST CENTRAL ILLINOIS

Field studies on populations of *Eubranchipus serratus* in east central Illinois during the spring season of 1936, 1937, and 1941, with a few observations on *E. vernalis* were published by Dexter and Ferguson in 1943. A series of annual visits was resumed in 1945 and has been continued to the present time. Visits were made in late March 1945-50. Both species formerly encountered were again collected although *E. vernalis* has been found only rarely. A third species, *Chirocephalopsis bundyi*, was discovered in one pond in 1948 and in another one in 1949, each time with a population of *E. serratus*,

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TABLE 1.—Collecting records of *Anostraca* in east central Illinois*

| Location of Ponds | Pond No. | 1936 | 1937 | 1941 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 |
|---|----------|------|------|------------|---------|---------|----------------|------------------------|--------------|--------------|
| Near Oakwood. Field ditch | 1. | A | — | A | drained | 0 | 7 | C | C | N |
| Near Homer. Flood plain pool | 1. | N† | 0 | 0 | 0 | 0 | dry | 0 | dry | dry |
| Near Homer. Flood plain pool | 2. | N† | 0 | dry | 0 | s† | 0 | 4† | c† | 7† |
| Near Homer. Flood plain pool | 3. | 2† | 0 | dry | 2† | 0 | 0 | 0 | s† | 0 |
| Near Urbana. Pasture pool | 7. | 0 | — | — | A | S | 0 | C | A | 5 |
| Near Urbana (Brownfield A) Pasture pool | 8. | A | A | S | A | C | 0 | A | A with 1‡ | 5 |
| Near Urbana. (Brownfield B) Swamp pool | 9. | C | C | nearly dry | C | N | 0 | C with 2‡ | A | C |
| Near Rantoul. (Pond along R. R. fill) | A. | A | C | 0 | N | drained | drained | S-partly drained | C | N |
| Near Rantoul. (Pond along R. R. fill) | B. | A | C | 0 | N | N | 0 | C | C | A |
| Near Rantoul. (Pond along R. R. fill) | C. | C | N | 0 | C | I | N | S | C | C |
| Near Rantoul. (Pond along R. R. fill) | D. | N | S | 0 | A | I | S | N | C | 0 |
| At Savoy. (Pond along R. R. fill) | 1. | 2 | 0 | dry | 0 | dry | de- stroyed | | | |
| At Savoy. Pasture pool | 2. | A | 0 | 0 | C | C | N | A | A | A |
| At Savoy. Pasture pool | 3. | A | S | N | A | N | S | N | A | A |
| At Savoy. Pasture pool | 4. | A | I | A | A | N | 0 | N | A | A |
| Near Tolono. Pool along R. R. fill | A. | A | — | — | 0 | dry | dry | pol- luted 0 | dry | dry |
| Near Tolono. Pool along R. R. fill | B. | A | — | — | C | N | nearly dry | mostly drained 0 | drain- ed | drain- ed |
| Near Seymour. Prairie pool | A. | N | S | — | C | C | 0 | N | 5 | 1 |
| Near Seymour. Prairie pool | B. | N | S | — | C | 0 | 0 | 0 | 0 | 1 |
| Near Seymour. Prairie pool | E. | 0 | 0 | — | 0 | 0 | 0 | 1 | 2 | 0 |
| Near Monticello. Roadside ditch | 1. | N | — | — | dry | — | — | — | — | — |
| Total number of records | | 19 | 10 | 4 | 14 | 12 | 5 | 14 | 15 | 13 |
| Percent of possible records | | 89 | 77 | 40? | 81 | 79 | 38 | 93 | 93 | 86 |

of *E. serratus*

* Numbers are the total number collected, when rare. A = abundant. C = common. N = numerous. S = scarce. † = *Eubranchipus vernalis*. ‡ = *Chirocephalus bundyi*. All other records are *E. serratus*. Dash (—) = not visited.

as noted earlier in this paper as a new species for the state of Illinois and as another instance of two species living in the same pond.

Table 1 summarizes the collecting records for all years, including those published earlier, for comparison. Symbols designating relative abundance show the annual fluctuation of these populations. Some of the interesting points brought out by this table are as follows. After the Oakwood pond was drained in 1945, no fairy shrimps were found the following year, although they had been abundant in certain previous years, and the season of 1946 was a favorable one in other ponds. In 1947, however, the shrimps returned in small numbers, and in the next three years were common throughout the re-established pond. Pond A at Rantoul was also drained. In 1948 some shallow water remained in the former depression, and a small population of *E. serratus* was found there. In the following two years it was common again as it usually is in the chain of ponds along the railroad fill in that locality (Plate I, fig. 4). Two ponds which did not have fairy shrimps in the earlier years of the survey acquired them in later years. Pond 7 near Urbana had none in 1936. In the spring of 1940 and 1941, Dr. C. C. Hoff found fairy shrimps there while collecting other biological materials. During visits by the writer in 1945, shrimps were found to be common or abundant there each year except 1947, when none could be found, and in 1950 when only five were collected (Plate I, fig. 5). Pond E at Seymour yielded nothing until 1948 when a single fairy shrimp was collected from this prairie pond. The following year only two were collected. Pond B near Seymour did not have fairy shrimps for four consecutive years after having a large population in the season of 1945. In 1950 a single specimen was found there.

The bottom row of Table 1 shows the annual fluctuation of the ponds investigated in terms of percent of possible records of *E. serratus*—i.e. the percent of ponds having this fairy shrimp in relation to the number of ponds which were known to contain this species at some time during the period of this study. The season of 1937 was much less favorable for fairy shrimps than the preceding year. The scanty collections of 1941 are explained partly by the late date of collection (April 11) and the early drying out of the ponds that year. From 1945 to 1947 there was a continual decline in fairy shrimp populations. Not only were fewer ponds inhabited each year, but seven of them had smaller populations each succeeding year during that interval. Three, on the other hand, yielded somewhat more specimens in 1947 than in the preceding year, but one of these had been drained in 1945 as described above. In general, the season of 1947 was the poorest one for fairy shrimps in these ponds of east central Illinois. It is interesting to note that according to Mrs. Margaret Groce Nagelsen, formerly a student at Lindenwood College, the population of *E. serratus* in a pond near St. Charles, Missouri, studied by her, was much less abundant in 1947 than in 1946 (Plate II, fig. 13). In 1948, on the other hand, conditions for fairy shrimps in east central Illinois were once again very favorable. Fairy shrimps returned to seven pools from which they were absent the preceding year and one was collected from a pool which never before yielded specimens. Four other ponds contained a larger population in 1948 than in 1947 and only one pool had a

smaller population in 1948 than during the preceding year. The season of 1949 proved to be the most favorable one for fairy shrimps during the period of this study. All stations but one which might have had fairy shrimps contained them. In general they were more abundant than in the preceding year with a single exception. Three species were collected in 1949—*E. vernalis*, *E. serratus*, and *C. bundyi*. *E. vernalis* as well as *E. serratus* was most abundant that year.

The same trend in fluctuation of abundance over the years reported here for *E. serratus* in Illinois was found in populations of *E. vernalis* studied in northeastern Ohio. Results of that investigation are published through 1950 (Dexter and Kuehnle, 1951).

SUMMARY

A study of the fairy shrimps of North America from field collections of the writer and specimens contributed by field biologists and museums has resulted in the following additions to our knowledge of the geographical distribution and ecology of these ephemeral crustaceans.

The known geographic range of 16 species has been extended by the acquisition of records from the following states, provinces, or regions not previously given in the literature: *Polyartemiella hanseni*—Northwest Territories. *Thamnocephalus platyurus*—Nevada, New Mexico, California. *Chirocephalopsis bundyi*—New Hampshire, Vermont, Illinois, Minnesota, South Dakota, Nebraska, Utah. *Eubranchipus vernalis*—West Virginia, Tennessee, North Carolina. *E. serratus*—Indiana, Montana, Washington. *E. holmani*—Georgia, North Carolina. *E. ornatus*—North Dakota, Montana, Nebraska. *E. oregonus*—Washington. *Artemia salina*—Puerto Rico, Nevada, North Dakota. *Branchinecta paludosa*—Nova Scotia. *B. shantzi*—Utah. *B. coloradensis*—Arizona, Nevada. *B. lindahli*—Nebraska, New Mexico, Arizona. *B. gigas*—Nevada, Utah. *Streptocephalus texanus*—Florida. *S. seali*—Nebraska, North Dakota.

Several additional collections of either rare species or specimens from localities where few have ever been known are placed on record.

The history of collections of fairy shrimps in the state of Florida is reviewed with the addition of recent records.

Eubranchipus floridanus n. sp. is described from Alachua County, Florida.

Branchinella alachua n. sp. is described from Alachua County, Florida.

New records of different species of Anostraca inhabiting the same pond are given. The following were collected together: *Chirocephalopsis bundyi* with *Eubranchipus serratus*. *C. bundyi* with *Streptocephalus seali*. *S. seali* with *S. texanus*. *E. floridanus* with *S. seali* and *S. texanus*. *B. alachua* with *S. seali*. *S. texanus* with *Thamnocephalus platyurus*. *S. seali* with *E. vernalis*. *S. texanus* with *Branchinecta lindahli* and *T. platyurus*. *S. texanus* with *B. lindahli*. *T. platyurus* with *Streptocephalus* sp. *E. vernalis* with *E. holmani*.

Some specimens have been discovered bearing anomalous appendages. These are: One *Eubranchipus vernalis* with a spine on the right clasper, and three immature specimens with abnormally developed antennal appendages; one *Streptocephalus seali* with a spinous growth on the right cercopod; one *E. serratus* lacking the antennal appendage on the right side, and four others

having a mixture of male and female antennae and antennal appendages on the same individual.

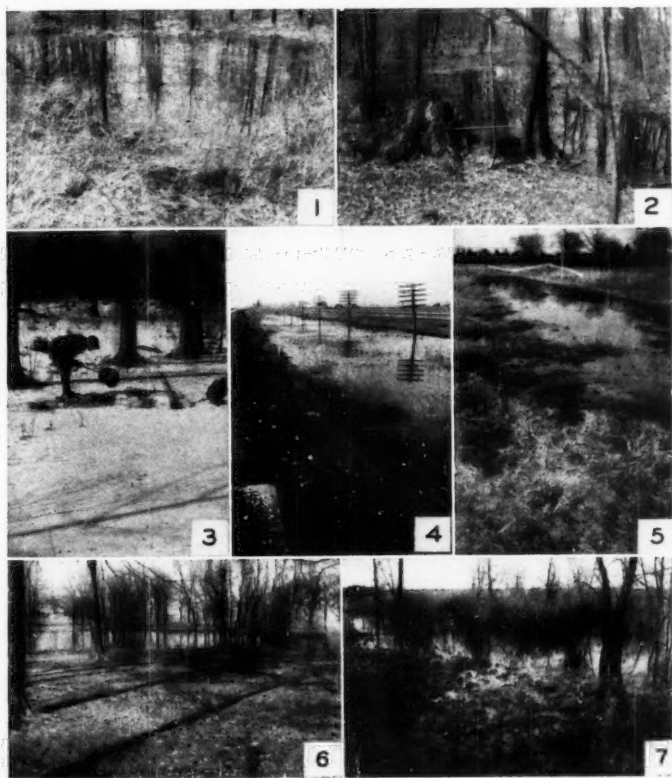
Fluctuations of populations of *Eubbranchipus serratus* in east central Illinois in the spring of 1945-50 inclusive are tabled and described and are compared with earlier published records. The populations of 1947 were the poorest while those of 1949 were the most abundant and widely spread during the term of this study.

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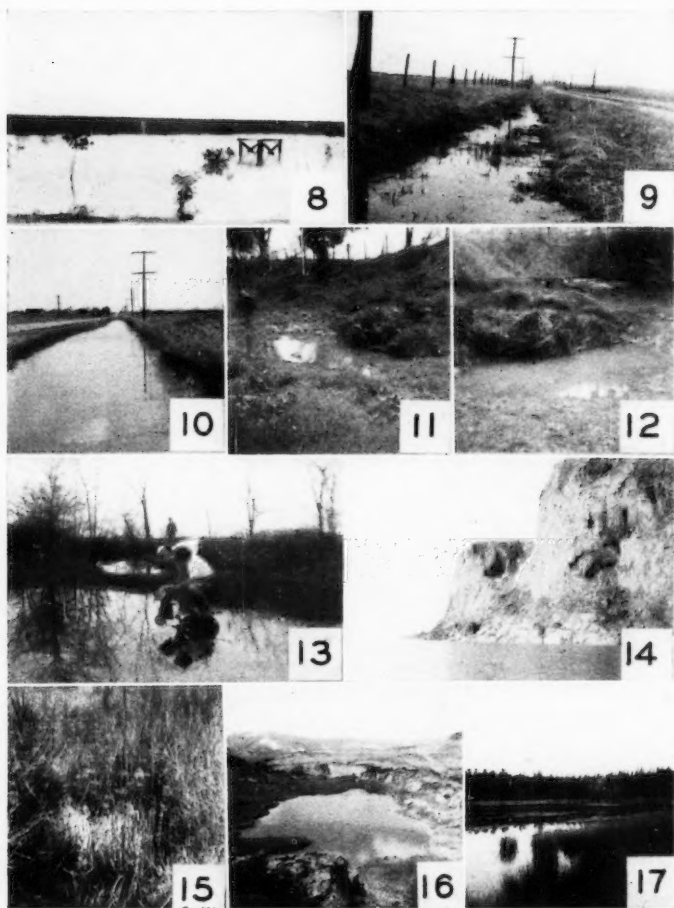
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PLATE I



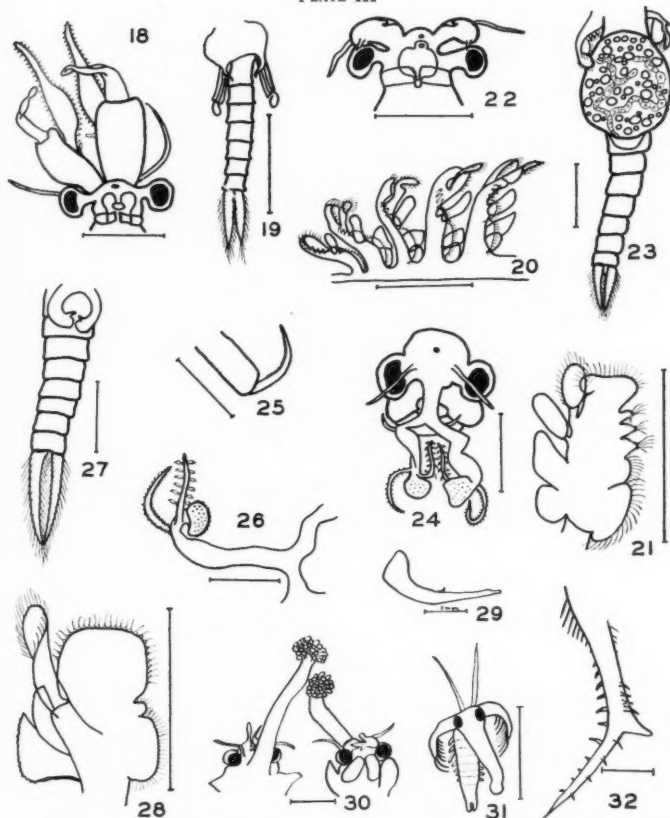
Figs. 1-7.—1. Typical temporary pond habitat of *Eubranchipus vernalis* in Ohio. Station no. P58 in Portage County; Woods pond in Geauga County which contains the only known large population of *Chirocephalus bundyi* in Ohio; 3. Collecting *E. vernalis* from a pond near Cushman, Massachusetts, Feb. 16, 1946. Photo by D. S. Lacroix; 4. Chain of ponds along railroad fill near Rantoul, Illinois, where *E. serratus* is found; 5. Field pond near Urbana, Illinois. Habitat of *E. serratus*. Pond 7; 6. Pasture pond near Brownfield Woods, north of Urbana, Illinois. Pond 8 (or Brownfield A). Site of finding rare specimens of *C. bundyi* with population of *E. serratus*; 7. Swamp pond near Brownfield Woods, north of Urbana, Illinois. Pond 9 (or Brownfield B). Site of finding rare specimen of *C. bundyi* with population of *E. serratus*.

PLATE II



Figs. 8-17.—8. Prairie lake near Clovis, New Mexico, where *Thamnocephalus platyurus* was found. From dried mud collected here *Streptocephalus texanus*, *Branchinecta lindahli*, and *T. platyurus* were hatched. Photo by K. S. Buchanan; 9-10. Roadside ditches near Lawrence, Kansas, from which *E. serratus* was collected. Photos by L. H. Ponder; 11-12. Temporary rain pools at Moorefield, West Virginia, where *E. vernalis* was found. Photos by L. W. Wilson; 13. Pond near St. Charles, Missouri, on flood plain of Mississippi River where *E. serratus* was collected. Photo by Margaret Groce Nagelsen; 14. Great Bear Lake, near Port Radium, Northwest Territory. A rain pool on rock bluff of this lake contained specimens of *Polyartemiella hansenii*. Photo by R. B. Miller; 15. Shallow temporary pool at Victoria, British Columbia, in which *E. oregonus* was found. Photo by P. H. D. Parizeau; 16. Tundra pond in Rocky Mountain National Park, Colorado, at an elevation of about 3475 meters. It contains *Branchinecta shantzi*. Photo by R. W. Pennak; 17. Muskee Lake, a permanent seepage lake near Boulder, Colorado, at an elevation of 2617 meters. *Streptocephalus seali* is found here. Photo by R. W. Pennak.

PLATE III



Figs. 18-32.—18. Male *Eubranchipus floridanus* n. sp. Ventral view of head showing characteristic second antennae and antennal appendages; 19. Male *E. floridanus*. Ventral view of abdomen with penes and cercopods; 20. *E. floridanus*. First five thoracic appendages from lateral view; 21. *E. floridanus*. Second thoracic appendage from posterior view showing the five endites and endopodite on the right and the proepipodites, epipodite, and exopodite on the left; 22. Female *E. floridanus*. Ventral view of head showing characteristic second antennae; 23. Female of *E. floridanus*. Ventral view of abdomen with egg sac and cercopods; 24. Male *Branchinella alachua* n. sp. Front view with frontal appendage extended downward; 25. Second antenna of male *B. alachua*; 26. Frontal appendage of male *B. alachua*. Ventral view of right branch extended forward; 27. Male *B. alachua*. Ventral view of abdomen showing penes and cercopods; 28. *B. alachua*. Thoracic appendage from posterior view showing endites and endopodite on the right and proepipodite, epipodite, and exopodite on the left; 29. Distal portion of male clasper of *Eubranchipus vernalis* with an anomalous spine; 30. Dorsal aspect of female (on left) and ventral aspect of male (on right) of immature *E. vernalis* with an asymmetrical and abnormal antennal appendage; 31. Larval *E. vernalis* with an abnormal growth on head; 32. Right cercopod of *Streptocephalus seali* with an abnormal spinous growth.

Re-descriptions of *Daphnia pulex* var. *pulicaria* Forbes, *D. thorata* F. and *D. dentifera* F.

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Subsequent to the re-description of two species of *Daphnia* which S. A. Forbes named from collections in Wyoming and Montana, additional material has become available which makes possible re-description of three other of his species. *Daphnia thorata*, *D. dentifera* and *D. pulex* var. *pulicaria* were described by Forbes in 1893. No illustrations accompanied the description of *thorata*. That of *dentifera* was supplemented by a drawing of an immature female. Only the male of the variety *pulicaria* was figured. No scale is given on either figure. Important details are missing in the textual description of these species, as they are for *Daphnia clathrata* and *D. arcuata* (Brooks, 1952). Although it is now necessary to supplement the descriptions of these five species, it must be emphasized that Forbes' descriptions are the best and most complete yet given for any North American *Daphnia*. When the writer has completed the revision of the North American *Daphnia* now in progress the taxonomic position of Forbes' entities relative to the others of this continent should be clear.

The interest and generosity of Profs. H. J. Van Cleave and Samuel Eddy have provided specimens from Forbes' personal collection. Prof. Eddy stated in a letter, "About 1925, Prof. Forbes gave me some of his early collections and I made permanent slides of his material. The material was in vials and Prof. Forbes did not identify any of the material I mounted."

Among these slides there were nineteen bearing *Daphnia* with labels indicating that they were from the type localities of *Daphnia pulex* var. *pulicaria*, *D. thorata* and *D. dentifera*. Six of the twelve slides from Yellowstone Lake, the type locality for *pulicaria*, bear the date, August 20, 1890. The itinerary for that year (Forbes, 1893) states that collections were made in Yellowstone Lake on that date. The other six slides from Yellowstone Lake bear the date September 1891, four stating the fifth day, and two the fifteenth. Examination of the itinerary indicates that collections were made on the fifth day but that the expedition had concluded its work by the tenth. The "15th" on the label is almost certainly a misprint for "5th." One of the four *Daphnia*-bearing slides from Flathead Lake carries the date of August 4, 1891, while the others say August 20. As the expedition did not leave Champaign, Illinois until August 10, and did collect in Flathead Lake on the twentieth, it can be concluded that August 20 is the correct date for the collection of all the material here represented from Flathead Lake. The three slides labelled "pond n. side of Shoshone Lake" also carry the date, July 23, 1890, which tallies with the itinerary.

MEASUREMENTS EMPLOYED IN DESCRIPTIONS

The following dimensions aid in the description of the shape of a *Daphnia*.

1. Carapace length—CL—measured from anteriormost extension to inflection point of concavity joining ventral edge of valves to shell spine. This distance is measured along the major axis of the ellipse to which the lateral projection of the valve is an approximation.
2. Carapace—CW—the greatest width of carapace normal to the major axis of carapace.
3. Head length—HL—the distance from the anteriormost extension of head back to the posterior surface of the lateral ridge formed by the antennule. This distance is measured along a line parallel to the major axis of the valve.
4. Head width—HW—measured from tip of rostrum to dorsal surface along line normal to head length.
5. Shell spine—SS—measured along its length.
6. Antennae—Two measurements were made. One from base of antennae to tip of ventral ramus, the other to the tips of the swimming hairs.
7. The greatest and least dimensions through the compound eye, including the lenses, are called "greatest and least diameters."
8. The diameter of a lens is the greatest width tangential to the eye. The largest and smallest lenses are measured.
9. Position of ocellus in relation to other cephalic structures always measured along line parallel to major axis of valves.

DAPHNIA PULEX var. PULICARIA Forbes

Fig. 1

Forbes, S. A., 1893, Bull. U. S. Fish Comm. 11: 242.

Forbes said of the collections from Yellowstone Lake, "Away from the shore, by far the most common crustacean was *Daphnia pulex*. Although in ordinary situations the males of *Daphnia* are by no means common, in our Yellowstone Lake collections, made in August and September, the males of this variety were many times commoner than the females, making sometimes nearly the whole of a large catch. The few examples of the other sex seen were mostly young, although a female bearing the ephippium occurred occasionally." (1893, p. 225) Concerning the assignment of this *Daphnia* to the species *pulex*, Forbes stated in a footnote, "The common and even abundant occurrence of this species in Yellowstone Lake as a form apparently pelagic in its habits (widely contrasted, consequently, with its usual character) was so unexpected and unusual that I hesitated long before assigning this *Daphnia* to the species most abundant in our stagnant pools. Prolonged study of it from various collections in the Park in comparison with those from the waters of Illinois, has finally led me to conclude, however, that this Yellowstone Lake form is not to be specifically distinguished from American examples of *pulex*. In order to furnish material for a more critical comparison than has hitherto been made of the American and European representatives of this species, I append a description, under the varietal name of *pulicaria*, based upon Yellowstone specimens, with figures of both sexes, (page 242 and plate XXXVII, fig. 1)." (p. 225).*

"A comparison of the collections made at and beneath the surface, by day and by night, in sunshiny and in cloudy weather, would seem to indicate that the lake variety of *Daphnia pulex* is much more sensitive to sunlight than any

* Only the male was figured.

other associated form. In collections made at the surface after dark, and in those made in sunny weather below the surface, this was many times the most abundant crustacean; but in similar collections made at the surface it was relatively rare, *Diaptomus sicilis* then taking the lead." (p. 226).

DESCRIPTION OF TYPES

Lectoholotype (A, Fig. 1).—Mature female with one egg in brood pouch, stained (boraxcarmine ?), lying on left side with dorsal margin of carapace slightly higher than edges of valves. Right antenna badly broken. Tear in dorsal margin of head at level of attachment of antennal levator. Indentation in dorsal margin of carapace opposite egg in brood pouch. Optic vesicle collapsed away from anterior margin of head. Anterior adductor and levator pulled away from attachment.

Dimensions: CL—1.15 mm., CW—0.9 mm., HL—0.26 mm., HW—0.53 mm., SS—0.48 mm., Antenna (to tips of ventral ramus)—0.67 mm., Antenna (to tips of swimming hairs)—1.08 mm.

Head: Head without crest but with mid-line of margin slightly raised or keeled. Keel just discernible over optic vesicle. Anteriormost extension of margin is the portion rounded over optic vesicle. Ventral margin posterior to the portion rounded over optic vesicle continues straight to rostrum. Viewed over entire extent, ventral margin of head is concave. Rostrum well marked, slightly bulbous at tip, deeply excavated on posterior surface immediately ventral to exerted tips of antennules. Median carina on posterior surface of head convex in lateral view, with greatest height dorsal to tips of antennules. Ventral continuation of carina between tips of antennules lower than these tips. Seven to 9 sensory hairs projecting from each antennule (H, Fig. 1).

Free edge of fornix convex, extending well over base of antenna. Anterior end of fornix on line drawn between posterior edge of eye and anterior end of attachment of anterior antennal adductor. The ridge into which fornix merges continues onto bulge over optic vesicle.

Both antennae much damaged. Structure as in male (D, Fig. 1).

Greatest diameter of eye, 115 microns; least, 80.

Tangential diameter of lens, 14 to 18 microns.

Ocellus of moderate size, 12 microns in diameter, ventral to level of ventral edge of eye. It lies slightly less than halfway between posterior surface of eye and posterior surface of antennule.

Carapace: Dorsal margin of carapace much less strongly curved than ventral edge. Base of shell spine placed well dorsal to a line drawn midway between dorsal and ventral margins. If the ventral edge of valve from a point opposite tip of rostrum to base of shell spine be divided in half, the spinules extend along entire posterior half of margin and a short distance onto anterior half. Spinules between 25 and 33 microns long over anterior half of spinulate margin; on posterior half, about $\frac{1}{2}$ this length. About 40 spinules on each edge. Spinule length equal to, or greater than, interspinule distance except between first 6 spinules. Dorsal margin spinulate except for anteriormost fifth of distance from junction with head-shield to base of shell spine. Fifteen spinules in each series. Spinule length less than interspinule distance. All spinules are 25 to 30 microns except for anterior 2 which are shorter. Spinules

from both dorsal and ventral margins continued onto shell spine where most spinules are about 30 microns in length.

Abdomen: First of the dorsal abdominal processes, glabrous, about twice length of second. Second with a few hairs at tip, third more pubescent with larger hairs. Fourth, a low, glabrous mound. (E, Fig. 1.)

Tooth-bearing portion of anal ridge slightly curved in convex sense. No bay dorsal to anal ridges. Twelve teeth on each side; the last one on the right side and last 3 on the left much smaller than others. Tooth length decreases gradually from distal end of series to proximal.

The two small teeth on ventral surface of postabdominal claw distinct. Pectination in usual three fields. Proximal comb of each claw with 6 teeth, the middle ones the longest (these teeth not in plane of focus in specimen drawn as G, Fig. 1). Middle comb of right claw with 5 teeth, that on left with 4. The first three teeth of each, beginning distally, slightly curved and about $2\frac{1}{2}$ times as long as longest teeth of proximal comb. Fourth tooth of each claw shorter and more slender than third. On right claw this fourth tooth just over $\frac{1}{2}$ the length of third; on left, just under. The fifth tooth on right claw stouter, but shorter than longest teeth of proximal comb. Fine teeth of distal comb about as long as, but less stout than, teeth of proximal comb. Number as indicated in G, Fig. 1.

Lectoparatype 1 (B, Fig. 1).—Mature female with two embryos in brood pouch, lying on left side, with median plane nearly parallel to slide. Stained (boraxcarmine?). Ventral edge of right valve folded back. Tear in edge of right valve at base of shell spine (not indicated in drawing). Shell spine broken off. All but proximal joint of left antenna broken off. Tissue of head shrunk away from anterior and dorsal margins of head (preserved shortly prior to molting). Right postabdominal claw broken off at base, but caught on edge of carapace.

Dimensions: CL—1.22 mm., CW—0.9 mm., HL—0.27 mm., HW—0.55 mm., SS—broken, Antenna (to end of ventral ramus)—0.75 mm., Antenna (to tips of swimming hairs)—1.05 mm.

Head: As in lectoholotype except that optic vesicle is not collapsed. Diameter of optic vesicle, 150 to 160 microns.

Greatest diameter of compound eye, 120 microns; least, 85. Tangential diameter of lens 18 to 22 microns. Ocellus directly posterior to ventralmost lenses of eye, of same size as in lectoholotype, but $\frac{1}{3}$ the distance from posterior surface of eye to posterior surface of antennules.

Carapace: Shape as in lectoholotype. Spinules on dorsal margin do not extend as far forward as in lectoholotype. Seventeen spinules in single row. Spinule length increases posteriorly from 20 to 30 microns.

Spinulation of ventral edge of valves covers same extent as in lectoholotype. Forty-three spinules on edge of left valve. (Right, difficult to count.) Spinules 20 to 25 microns long over anterior half of spinulate margin, decreasing rather abruptly to 12 to 20 over posterior half.

Abdomen: Abdominal processes as in lectoholotype. Anal ridge very slightly sinuate with concavity at level of teeth 5 to 8 (counting from claw) on right side and teeth 6 to 8 on left. Twelve anal teeth on each side. First

5 anal teeth on each side of much the same length, thereafter gradually diminishing.

The two fine teeth on ventral surface of postabdominal claw distinct. Seven teeth in proximal comb of each claw, middle ones the longest. Teeth

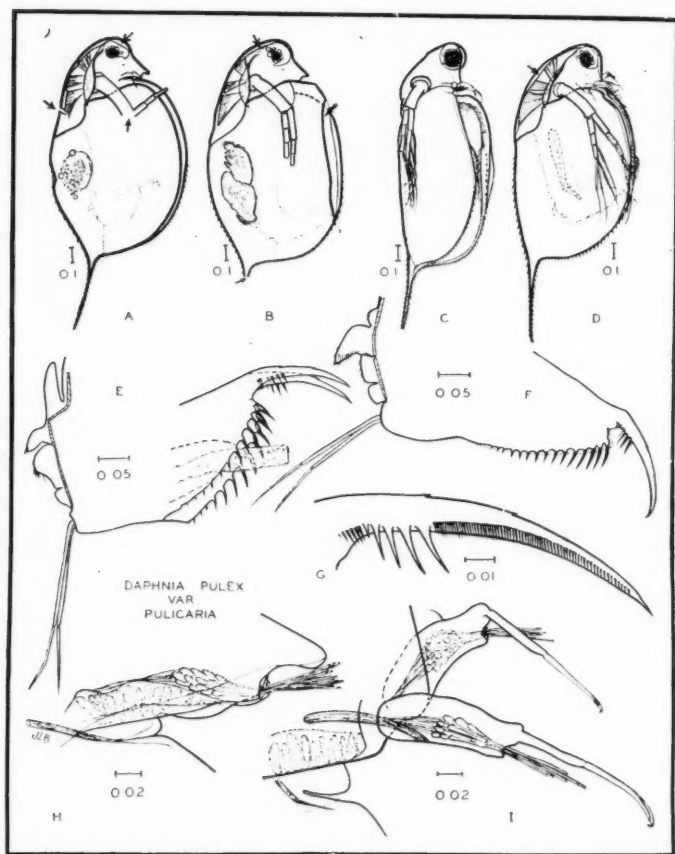


Fig. 1.—*Daphnia pulex* var. *pulicaria* Forbes: A. Lectoholotype, mature female, lateral view. B. Lectoparatype 1, mature female, lateral view. C. Male ventro-lateral view to show hairs growing from inner rim of ventral margin of valves. D. Lectoallotype, lateral view. E. Lectoholotype, post-abdomen, lateral view. (Fecal mass projecting from anus). F. Lectoallotype, postabdomen, lateral view. G. Lectoholotype, right postabdominal claw, lateral aspect. H. Lectoholotype, rostral portion of head in lateral view. I. Lectoallotype, rostral portion of head in lateral view.

Drawn with aid of camera lucida. Scales in millimeters. Arrows indicate artifacts.

of proximal comb of left claw in plane of focus. Longest of these teeth just over $\frac{1}{2}$ the length of longest teeth of middle comb. Proximal comb of right claw obscured by overlying structures. Middle comb of right claw with 5 teeth. The three distal ones stout, slightly curved and of equal length. The fourth less stout, straight and about $\frac{3}{4}$ the length of first 3 (tip of fourth tooth broken off). Fifth tooth, bent, appears about $\frac{1}{2}$ the length of fourth. Five teeth in middle comb of left claw of same relative size as those on right claw. Distal comb as in lectoholotype.

Lectallotype (D, Fig. 1).—Mature male with sperm in testis (stippled area in figure) lying on left side with dorsal margin of carapace slightly lower than ventral edge of either valve. Stained (boraxcarmine?). Some shrinkage of tissues away from exoskeleton especially along anterior margin of head. Optic vesicle partly collapsed. (Specimen preserved just prior to molting.) This shrinkage indicated by arrow in figure.

Dimensions: CL—1.17 mm., CW—0.81 mm., HL—0.3 mm., HW—0.53 mm., SS—0.55 mm., Antenna (to end of ventral ramus)—0.7 mm., Antenna (to tips of swimming hairs)—1.1 mm.

Head: Head with slight keel. Anteriormost extension of head is over optic vesicle. Ventral margin of head very nearly straight, parallel to body axis. Shallow concavity opposite ocellus. Configuration of rostrum as drawn in I, Fig. 1. Rostrum with blunt tip, emarginate between bases of movable part of antennules. Antennule composed of basal joint and a flagellum of about the same length.* Basal joint articulates with head proper, not with antennular ridge which flanks posterior surface of head. Distal end of antennular ridge immediately dorsal to articulation. Basal joint curved, convex on both its lateral and anterior aspects. The lateral hair arises from this basal joint about $\frac{1}{4}$ the length of joint from distal end. There are 6 to 7 sensory hairs arising from end of each basal joint. There is an articulation, or at least a constriction, near the middle of flagellum. The exoskeleton distal to this constriction is thinner than in proximal part. Flagellum about twice as long as longest sensory hair, and bearing hook at its tip.

Antennae, when folded against body, do not reach to posterior end of carapace. Swimming hairs of antenna two-jointed, joints of equal length.

Greatest diameter of eye, 130 microns; least, 106 microns.

Ocellus, 10 microns in diameter, posterior to middle of eye, not quite halfway from posterior edge of eye to posterior edge of antennular ridge.

Carapace: Dorsal margin of carapace from apex of head shield to tip of shell spine nearly straight, only slightly convex along carapace proper. Seventeen spinules in each series.

In D, Fig. 1, the ventral margin of right valve is indicated with its spinules but without its hairs. The hairs drawn all arise from ridge along medial surface of margin of left valve. The arrangement of hairs and spinules of ventral margin can best be understood from a specimen viewed ventrolaterally, as C, Fig. 1. Here the spinules and hairs of both valves are drawn. Conspicuous hairs project from the inner ridge along anterior half of valve's

* The flagella as drawn in I, Fig. 1, look relatively longer than their respective basal joints because the basal joints are foreshortened while the full length of each flagellum is in the focal point.

margin, while posterior half supports fine spinules. The manner in which the hairs and spinules differ in size and in the direction in which they project can best be understood by comparing the drawings C and D of Fig. 1. All of the hairs are feathery, which is not indicated in the drawings. The conspicuous spinules along the outer rim of posterior half of valve's edge number about 36, the first 18 of which are longer and farther apart than the second. Spinules from both margins continued onto shell spine.

Abdomen: The second dorsal abdominal process elongate and hairy; others low and glabrous.

Distinct bay on dorsal margin of postabdomen (cf. F, Fig. 1). Anal ridge nearly straight except at distal end. Thirteen teeth plus a pair of tiny spinules on right ridge; the left (the base of which is indicated by pecked line in drawing) bears 14, plus a tiny spinule. In each series the distal 5 teeth are long, thin, curved and about the same length. The length in the rest of the series gradually decreases, except that the last two teeth on each side are noticeably smaller than the preceding one.

Claw as in female.

COMPARISON OF LECTOTYPES WITH ORIGINAL DESCRIPTION*

FEMALE

SIZE AND SHAPE

1. "Length of adult female 1.9 millimeters without the spine; depth 1.1 millimeters; spine 0.5 millimeter. Female bearing ephippium, a little deeper (1.2 millimeters)."

Lengths of lectoholotype and lectoparatype 1 are 1.5 and 1.52 mm., respectively, when measured to base of shell spine as Forbes did.

Greatest depth of each is 0.9 mm.

Shell spine of lectoholotype, 0.47 mm. long.

Largest female in collection is 1.8 mm. long. This specimen is tipped and greatest depth appears to be about 1.2 mm.

2. "Similar, especially in female, to typical *D. pulex* to which it is closely related by its more general characters. Body a broad oval, moderately thick, colorless."

HEAD

1. "The head of the female is small, somewhat depressed, crested as in *D. pulex*, the crest extending backward to opposite the heart, and extending anteriorly to the eye."

The head is small, but the crest is so slightly developed that to mention it is misleading. The mid-line is indeed raised, but only slightly. This is demonstrated by closeness of optic vesicle to margin of head when seen in lateral view.

2. "The lower border of the head is broadly concave and the beak is long and applied against the anterior margin of the shell." "The beak projects a little beyond the tips of the sensory hairs";

* All of the original description is quoted, although the order of the sentences has been altered. If original description is clearly applicable to the lectotypes no comment is made.

Ventral margin of head is concave and beak (rostrum) is relatively long, although only about as long as, or slightly shorter than, sensory hairs (cf. H, Fig. 1). The posterior surface of head, but not the beak, is applied to the anterior margin of valves.

3. "fornices terminating posteriorly opposite the heart, and extending anteriorly to the eye."

Forbes has here again (cf. Brooks, 1952) considered the suture between head-shield and carapace to be an extension of the fornix. The posterior end of fornix proper is certainly just anterior to mandibular articulation (indicated by small arrowheads in A and B of Fig. 1), while anterior end is dorsal to posterior edge of eye.

4. "the eye is large, its vertical diameter contained scarcely twice in the distance from the eye to the tip of the beak, placed close to the broadly rounded anterior margin of the head, and provided with many lenses."

5. "Pigment speck of moderate size, midway between the eye and the posterior margin of head."

Ocellus is just under halfway from posterior edge of eye to posterior surface of antennular ridge.

6. "Antennae but moderately developed, destitute of scale-like appendages like those of *pulex*, but set with inconspicuous transverse rows of rather slender hairs. Swimming hairs moderate and moderately feathered, three-jointed, the third segment very short but evident."

Swimming hairs are two-jointed. A small knob just distal to the articulation was apparently mistaken by Forbes as another articulation.

Meaning of "moderate" difficult to assess.

7. "The coecum of the intestine strongly curved, extending at first obliquely downwards toward the middle of the eye, and then turning almost directly upward at an acute angle, terminating midway between the middle of the upper margin of the eye and the front of the base of the antenna."

8. "... commonly without dorsal emargination between the head and thorax, although sometimes in the generation of females bearing ephippia there is a broad concavity just above the heart."

There are no ephippial females in collection.

CARAPACE

1. "the margins, both dorsal and ventral are provided with backward-projecting spines or thorns as far as the middle. The anterior half of both margins smooth."

Spinulation on ventral edge of valves extends a very short distance onto anterior half of margin. However, spinulation on dorsal margin extends somewhat farther forward.

2. "The surface of the valve is marked with quadrate areolations."

This areolation, not conspicuous in any of the lectotypes, is of no taxonomic significance.

3. "Moderately long posterior spine placed above the middle line"; "The posterior spine is variable in length, reaching in adult females a fourth the entire length of the head and body."

In the lectoholotype shell spine is about $\frac{1}{3}$ the length of head and cara-

pace. Shell spines of other mature females are, however, shorter than this, more nearly of the relative size which Forbes designates.

ABDOMEN

1. "Dorsal processes of abdomen distinct, the two anterior contiguous in their origin, not united at their base, the first the longer, smooth and directed forward, the second hairy, turning backward. Two others in the form of low elevations, the last inconspicuous, both hairy."

The only exception to this statement concerns the hairiness of fourth process. It is not possible to discern any hairs on this process in either lectoholotype, lectoparatype 1 or any of the other mature females in the collection, even though the hairs on second and third are conspicuous in all specimens.

2. "The abdomen is rather broad, the posterior margin broadly rounded, the anterior margin straight; 13 to 17 spines bordering the anal furrow, length regularly increasing from above downwards." "with 14 to 17 curved spines at the anal furrow."

The first sentence is accurate, but the two statements about the anal teeth not only are inconsistent but do not accurately describe the specimens of the collection. The lectoholotype has 12 anal teeth on one side, 13 on the other. Lectoparatype 1 has 12 on each side. Ten other mature females have the following numbers of anal teeth, 13-13, 13-10(+), 13-14(+), 13-12, 14 (other side obscured), 12-13, 11-10(+), 12(+)-15, 12(+)-14(+), and 14(+)-17. In addition there were several tiny spines at proximal end of each series marked with a (+). There were two and six, respectively, following the two series with only 10 teeth each, 1 or 2 in the others. The last pair of figures pertains to the largest female in the collection. It can be said therefore that the usual number of anal teeth in a mature female is 12 to 14, with a possible range of 10 to 17. The largest mature ones may have more than the usual number, and immature females usually have 9 to 11.

3. "the teeth of the caudal claw in two groups of from four to six each, the upper group very much the smaller: the anterior margin of each claw with two distinct slight emarginations, as in *D. pulex*."

The proximal comb ("upper group") has either 6 to 7 teeth not only in female lectotypes but in five other mature females as well.

The middle comb has 4 to 5 teeth. Four of the 7 mature females have 4 teeth in the middle comb of one claw and 5 in the other; 2 have 5 in each, and one (the largest) has 4 in each.

MALE

SIZE AND SHAPE

1. "Length without spine, 1.4 millimeters; depth 0.9 millimeter; spine 0.33 millimeter."

Length of lectoallotype, 1.47 mm.; depth 0.78 mm. (low, specimen tipped); shell spine 0.6 mm. In one of largest males, these dimensions are 1.55, 0.95, and 0.48 mm. respectively.

2. "the male smaller, narrower, with head more depressed, the dorsum especially more nearly straight and the posterior spine standing higher, continuing the line of the dorsum backwards."

The females which Forbes described were larger and the males smaller than the lectotypes, for mature individuals of both sexes are of much the same size among the latter. The shape of the carapace, and shell spine is as described.

HEAD

1. "The lower margin of head is only slightly concave, the posterior half of it straight. A slight beak is formed just below the sensory antennae, the latter being attached at a slight angular emargination at the posterior angle of the head. From this emargination the posterior margin of the head passes directly upwards in a broad and gentle curve."

2. "Sensory antenna slightly clavate, slightly expanded at the middle, its length equal to the vertical diameter of the eye."

The structure which Forbes calls the "sensory antenna" has been here termed the basal joint of the antennule. His description is applicable but not very useful.

3. "In front of the terminal group of sensory hairs is a long terminal spine, nearly as long as the antenna itself, slightly curved backwards and segmented at the middle. Accessory hair distant from end but a little below the middle."

"Terminal spine" is flagellum.

4. "The eye is very large, placed at the very front of the head. Its longitudinal diameter is contained but once in the head behind the eye."

ABDOMEN

1. "A single hairy dorsal abdominal process, as in *pulex*."

The second abdominal process approaches more closely the relative size which Scourfield (1942) gives as characteristic of *D. obtusa* than of *D. pulex*. However, the presence of a few hairs on the third and none on the fourth is intermediate between *pulex* in which they are both hairless and *obtusa* in which they are both hairy.

DIAGNOSIS OF DAPHNIA PULEX VAR. PULICARIA Forbes*

FEMALE

Dimensions: Carapace length of first instar (represented only by a molted exoskeleton) is about 0.65 mm. That of the largest female is just twice that. Body proportions of first instar in relative terms are: $CW = \frac{3}{4} CL$, $HL = \frac{1}{3} CL$, $HW = 2 HL$, $SS = CL$. Proportions of largest female are the same as those of lectoholotype.

Head: Margin with small keel which is lowest over optic vesicle. Head longest at optic vesicle. Ventral margin of head concave. Ventral margin of rostrum straight or slightly convex in largest female. Anterior and dorsal margin continuously rounded as far as posterior end of antennal levator attachment. Slightly convex thence to apex of head shield.

Configuration of posterior surface of head varies little from that of lectoholotype (H, Fig. 1). Fornix relatively wide dorsal to antennal base with free edge convex in lateral view. At level of middle of attachment of anterior

* Based upon lectotypes and undesignated specimens from the type collection.

antennal adductor fornix becomes much narrower, curving toward anterior edge of eye. Halfway there, it is reduced to a low ridge which almost reaches eye. More than half of head length taken up by optic vesicle. Greatest diameter of eye in small ovigerous female, 100-200 microns; 150 in largest; ca. 80 in immature instars. Ocellus of moderate size, 10-15 microns in diameter, placed about $\frac{1}{3}$ the distance from posterior surface of optic vesicle to posterior surface of antennular ridge.

Carapace: Shape of carapace in mature females as in lectoholotype and lectoparatype 1. Dorsal margin straight in neonatae.

The number of spinules and their lengths on the ventral margin are the same in all instars. There are 40-43 spinules. Those on anterior half of spinulate margin are 24-28 microns long. They decrease over posterior half, reaching $\frac{1}{2}$ that length or less near base of shell spine.

The relative length of spinulate portion of ventral margin, however, does change with age, as does the interspinule distance. In the neonata, spinules cover about $\frac{3}{4}$ of ventral edge from base of shell spine to opposite rostrum. In the largest female they extend only over posterior half of this portion of the free edge of valve. Interspinule distance in the neonata is about $\frac{1}{2}$ the spinule length except between the few smallest spinules near base of shell spine where this distance is about the equal of spinule length. In mature females the distance between the long anterior spinules is greater than spinule length. The relative distance between spinules decreases posteriorly so that it is but the equal of spinule length at posterior end of margin.

The number and size of the spinules on dorsal margin of carapace also show no significant variation with age. There are 15-18 spinules in a single series, all of which are 24 to 30 microns long, except for a few shorter ones at anterior end. The spinulation in the neonata extends to apex of head shield, while in mature females as much as $\frac{1}{4}$ of dorsal margin of carapace may be free of spinules. In the neonata inter-spinule distance is about as great as spinule length, while in mature females it is always greater than spinule length.

Shell spine in the neonata is about as long as carapace and is set at an angle of about 30° dorsal to body axis. Shell spine does not increase in length during subsequent growth. That of lectoholotype (A, Fig. 1) is relatively the longest found among the mature females of the collection and is about the same absolute length as that of the neonata. Whether the absolutely shorter shell spines of other mature specimens have been broken off and partially regenerated, or have regressed, is impossible to judge. The angle which the spine of lectoholotype makes with body axis is about the maximum found among any of specimens other than the neonata. In many specimens, both immature and mature, spine is parallel to body axis, having the appearance of spine of male (D, Fig. 1).

Carapace extends posteriorly well beyond base of anal setae when thorax is extended (cf. A, B, Fig. 1).

Abdomen: First abdominal process glabrous, twice as long as second, with base about as wide (i.e. in lateral view). Second and third processes pubescent, of about same length, the third being the wider at base. Fourth

process is a low, glabrous mound. (It should be noted that Forbes described the fourth process as hairy.) Appearance of processes in E, Fig. 1, characteristic.

Anal ridge convexly curved or occasionally with suggestion of concavity in middle of tooth-bearing portion. Twelve to 14 anal teeth on each ridge. Thirteen is the modal number and 10 and 17 the limits of variation in mature females. Immature specimens have 9 to 11 teeth. Tooth length diminishes gradually from distal to proximal end of series (cf. E, Fig. 1).

The two emarginations on ventral surface of postabdominal claw are distinct. Pectination is in three combs of which the proximal has 6 or 7 teeth, the middle, 4 or 5, and the distal comb, many fine teeth (see under Comparison).

Distal three teeth of middle comb moderately stout and curved. Sometimes all three are stout and curved to the same degree: often stoutness and curvature decrease progressively in proximal two large teeth (as in G, Fig. 1). Fourth tooth thinner than third, usually straight, occasionally with slight curvature. Fourth tooth somewhat shorter than distal three (ca. $\frac{2}{3}$ their length). Fifth tooth when present is short and straight, placed more laterally on claw than others, and close to distal member of proximal comb.

Longest teeth of proximal comb about $\frac{1}{2}$ that of longest in middle comb.

Longest teeth of distal comb as long as but much thinner than teeth of proximal comb.

MALE

Dimensions: Carapace length of largest male in the collection is 1.3 mm. which is slightly under the size of largest females (1.35-1.40 mm.). Most of males in the collection are about the size of lectotypic male, and sperm is evident in testes of most of this size. Proportions as in lectoallotype.

Head: Head similar to female except for ventral margin and rostral portion which are as in lectoallotype. Little variation in this portion from structure of lectoallotype. The emargination at apex of rostrum which is broad and shallow in lectoallotype sometimes is much deeper at its antero-ventral end. Articulation of antennule sometimes not as far removed from ventral end of antennular ridge as in lectoallotype. Structure of antennule is constant from specimen to specimen. The distal part of flagellum may, however, be strongly curved.

Carapace: The degree of development of "shoulder" of carapace at antero-ventral margin is rather variable. That of lectoallotype is intermediate. The hairs on inner margin as in C, D of Fig. 1, although difficult to see in certain orientations. Usually about 40 spinules along outer rim of posterior half of ventral margin. The anterior spinules may arise from mesial side of valve margin and be difficult to see (cf. C, Fig. 1).

Seventeen to 24 spinules in each series on dorsal margin extending nearly to apex of head shield (often closer than in lectoallotype). Spinules 25-40 microns long.

Shell spine either parallel to body axis as in lectoallotype, or making slight angle dorsally.

Carapace extends posteriorly well beyond base of anal setae when thorax

is extended in long axis (cf. D, Fig. 1).

Abdomen: First dorsal abdominal process very small. Second relatively long, broader and more hairy than second process of female. Often longer than in lectoallotype figured. Third process is large mound, but not as large as that of female; pubescent. Fourth process small, glabrous.

The bay anterior to anal furrow always well developed (cf. F, Fig. 1).

The anal ridges on 8 males have from 10 to 14 teeth, all but 3 (of the 16 ridges) had 12-14. The last (i.e. most proximal) teeth of these were often irregular in size and position and all but three were followed by a small double spine or several tiny spinules.

The size and number of teeth in proximal and middle combs of post-abdominal claw are more variable than in the female. Five and 6 are the usual numbers of teeth in proximal comb, 7 occasionally. Sometimes when 5 are present the teeth are conspicuously larger than is usual for either male or female (cf. G, Fig. 1). Ten of the middle combs on 7 pair of claws have 5, 3 have 6, and one has 4 teeth. When 6 teeth are present, the fifth is slightly shorter and thinner than fourth, and sixth is of the size of the most proximal in lectoholotype (G, Fig. 1). The distal 4 teeth of middle comb of the male tend to be more similar to each other in size and shape than do the corresponding teeth in the female.

LOCALITY OF *DAPHNIA PULEX* VAR. *PULICARIA*

"Yellowstone Lake and other waters of Yellowstone Park."

In the discussion of the collections Forbes reported *Daphnia pulex* from several ponds but never, except for the Yellowstone Lake collections, indicated that the new varietal name was applicable. We must, therefore, take Yellowstone Lake alone as the typical locality.

DAPHNIA THORATA Forbes

Fig. 2

Forbes, S. A. 1893, Bull. U. S. Fish Comm. 11: 241.

"This species belongs to the *hyalina* group, and may possibly be entitled only to varietal rank. The distinctness and constancy of its characters, however, in collections made by us in Flathead and Swan Lakes in western Montana, and the number of minor points in which it differs from *hyalina*, as most recently described, lead me to distinguish it here as a specific form." (first paragraph of the description of *thorata*, p. 241.)

"The open water collections in Flathead Lake were very similar in general character and in the relative numbers of the principal groups to those in Yellowstone Lake but the species were all different. In the former lake the so-called *Daphnia pulex* was not once seen, but this species was replaced by a *Daphnia* allied to *hyalina*, and here described as *thorata*. This entomonstracan made probably four-fifths to nine-tenths of the product of every deep-water haul with the surface net." (p. 238)

DESCRIPTION OF TYPES

Lectoholotype (B, Fig. 2).—Mature female with one embryo in brood pouch, lying on left side. Stained (boraxcarmine?). Fold in cuticle of right side of head; fold in right valve near and parallel to margin (not indicated in drawing). Slight indentation in dorsal margin of carapace.

Dimensions: HL—0.69 mm., HW—0.80 mm., CL—1.65 mm., CW—1.08 mm.,

SS—1.00 mm., Antenna (to end of ventral ramus)—1.0 mm., Antenna (to tips of swimming hairs)—1.5 mm.

Head: Head with well-developed helmet. Optic vesicle remote from ventral margin of head. Anterior margin of helmet smoothly rounded. This curve continued on ventral surface to level of posterior edge of eye, where it passes concavely to the convexly expanded rostrum. Tip of rostrum exceeds length of sensory hairs. The greatest depth of carina on posterior surface of head is dorsal to tips of antennules but carina extends to tip of rostrum. Carina describes a gentle concave curve from its point of greatest depth to tip of rostrum. Carina higher than tips of antennules as it passes between them. Carina at its dorsal end drops to, or below, posterior surface of antennular ridge.* Right antennular ridge is distorted by fold in cuticle.

Dorsal margin of helmet runs straight back to a point over attachment of anterior antennal adductor. Margin follows gentle convex curve from this point of apex of head shield. Anterior end of fornix distinctly posterior to eye. Ridge into which it continues ends opposite middle of eye. Fornix shallow, its free border nearly straight and parallel to body axis. Posterior end of fornix well in front of mandibular articulation (cf. B, Fig. 2, where arrowhead indicates point of articulation).

Optic vesicle elongate in direction of body axis. Eye small: greater diameter, 95 microns; least, 75 microns. Tangential diameter of lens, 16-25 microns. Ocellus small, 10 microns in diameter, more than $\frac{1}{2}$ the distance from posterior surface of eye to posterior surface of antennular ridge.

The two joints of the swimming hairs of about equal length. Terminal swimming hairs of same length as ramus bearing them.

Carapace: Carapace an elongate oval, twice as long as wide. Body to base of anal setae only extends about $\frac{2}{3}$ the length of carapace. Anterior margin of carapace curves abruptly into ventral margin which continues with about same curvature to base of shell spine. Spinulation on dorsal margin confined to posterior third. Spinules small, relatively smaller than indicated in drawing (B, Fig. 2), the longest about 15 microns. Seventeen spinules in single series. Interspinule distance as long or longer than spinules. Spinulation over almost entire extent of ventral margin. Only a short bit at the anterior end smooth. Spinules about 25 microns long over anterior third of spinulate margin. Behind that, gradually decreasing to $\frac{1}{2}$ this length. Spinules always shorter than distance between them. Sixty-three spinules on each margin.

Shell spine arises dorsal to mid-line and projects at an angle of about 30° dorsal to mid-line. Spinulation from margins of carapace continued onto shell spine. Spinules relatively long (ca. 25 to 35 microns) over most of its length.

Abdomen: Anterior two abdominal processes obscured by overlying embryo. Third and fourth as in lectoparatype 1. Anal ridge more strongly sinuate than in lectoparatype figured (D, Fig. 2), with teeth 10 to 12 in bottom of concavity. Fifteen teeth on right ridge, 18 on left. Teeth decrease

* The body of this antennular ridge is composed of large cells which are indicated in C, Fig. 2).

rapidly in size from distal to proximal. Teeth 9 to 12 about $\frac{1}{3}$ length of first.

Postabdominal claw as in lectoparatype 1.

Lectoparatype 1.—Female, undoubtedly mature, but with no eggs or embryos in brood pouch. Lying on left side and stained (boraxcarmine?). Transverse fold across head. Right valve deformed by longitudinal fold near and parallel to dorsal margin and reaching base of shell spine. Levator muscle torn away from attachment. Right fornix folded in middle.

Dimensions: HL—0.675 mm., HW—0.93 mm., CL—1.55 mm., CW—ca. 1.2 mm. (distorted by folding), SS—0.85 mm., Antennae (to end of ventral ramus)—0.98 mm., Antenna (to tips of swimming hairs)—1.45 mm.

Head: Anterior, ventral and dorsal margins similar to lectoholotype. Carina on posterior surface of rostral portion of head deeper than in lectoholotype not only dorsal to tips of antennules but also between them. The shape and great depth of dorsal part of carina when compared to all other specimens make it probable that this structure is distorted.

Fornix, although distorted by a fold, appears similar to that of lectoholotype.

Antennae as in lectoholotype.

Optic vesicle more nearly spherical than in lectoholotype. Eye of moderate size; its greatest diameter is 90 microns; least, 75. Tangential diameter of lenses, 16-20 microns. Ocellus of same size as in lectoholotype (i.e. 10 microns in diameter) and nearly $\frac{2}{3}$ the distance from posterior surface of eye to posterior surface of antennular ridge.

Carapace: Carapace deeper relative to length than in lectoholotype. Spinulation extends forward on dorsal margin for about half its length. Twenty-two spinules in a single series. Most of spinules are broken. Spinules on ventral edge of valves extend over the same relative distance as in lectoholotype. Sixty-five on edge of left valve, with spinules longer over anterior half of margin than over posterior, as in lectoholotype. Spinulation on shell spine as in lectoholotype.

Abdomen: First abdominal process almost twice as long as second or third, and glabrous. Second process tapering, sparsely hairy. Third, broadly rounded, hairy. Fourth, only a low mound apparently without hairs (cf. D, Fig. 2). Dorsal margin of postabdomen as drawn. Anal ridge sinuate with teeth 10 and 11 (counting from distal end) arising from bottom of concavity. Fifteen teeth plus double spinule on right side, and 14 on left.

Postabdominal claw with two distinct teeth on ventral margin. Pectination consists of three combs of fine teeth of much the same length. The teeth of proximal and middle combs of same length throughout but those of distal comb decreasing in length distally. The middle field extends to about halfway between the two ventral emarginations (cf. A, Fig. 2).

Lectoparatype 2.—Female, probably adolescent, as another specimen of this size has eggs in brood pouch; lying on left side. Stained (boraxcarmine?). Shell spine broken off from the carapace but still on slide.

Dimensions: CL—1.3 mm., CW—0.93 mm., HL—0.485 mm., HW—0.54 mm., SS—0.83 mm., Antenna (to tip of ventral ramus)—0.865 mm., Antenna (to tips of swimming hairs)—1.3 mm.

Head: Helmet less elongate, its anterior margin more broadly rounded than lectoholotype. Ventral margin of rostrum straight, its tip more blunt, not extended as far posteriorly as in lectoholotype.

Rostral portion of head is seen in almost perfect lateral view, as can be judged from relative position of antennule tips, left tip being indicated by a pecked line in C, Fig. 2. Carina on posterior surface of head is well developed with its greatest height just dorsal to tips of antennules. It is distinctly higher than tips of antennules as it passes between them. Edge of carina describes a gentle arc from its dorsal end to about midway between tips of antennules and apex of rostrum. Here there is a distinct concavity. Carina extends to apex of rostrum. The configuration of rostral portion of head of lectoparatype 2 and that of lectoholotype the same except for elongation of apex in lectoholotype (cf. B, C, Fig. 2).

COMPARISON OF LECTOTYPES WITH ORIGINAL DESCRIPTION*

SIZE AND SHAPE

1. "Length 2 millimeters to 2.5 millimeters; depth half the length, sometimes a little more."

The mature females fall within these limits of length and are about of this width.

2. "It is oval in outline."

HEAD

1. "The length of the head is about a third that of the valves of the shell excluding the spine and there is no trace of a dorsal emargination between head and body."

In the lectotypes the head is just under $\frac{1}{2}$ the length of valves and in smaller specimens closer to $\frac{1}{3}$.

2. "The head is narrowed toward the base and elongated forward in a way to give it the outline of a high bell jar with a flaring base. Its front is broadly and regularly rounded, its ventral margin usually conspicuously concave and closely like the dorsal, although occasionally the head is straight or convex beneath. The posterior margin is either straight or slightly concave."

3. "and the beak stands free from the front margin of the valves, and by its extension downward not only covers the antennae but reaches clearly beyond the tips of the sensory hairs."

This is correct enough for mature females, but in the smallest individuals the rostrum is not elongate.

4. "The eye is of medium size, placed far back of the front of the head and equidistant from the tip of the beak and the dorsal junction of the head and body."

If "the dorsal junction of the head and body" refers to the apex of the head shield, the distance to the eye is much greater than the distance from rostral apex to eye. If this phrase refers to the junction of these two body

* All of the original description is quoted, although in different order, except Forbes' first paragraph which is quoted above in the general remarks about *thorata*.

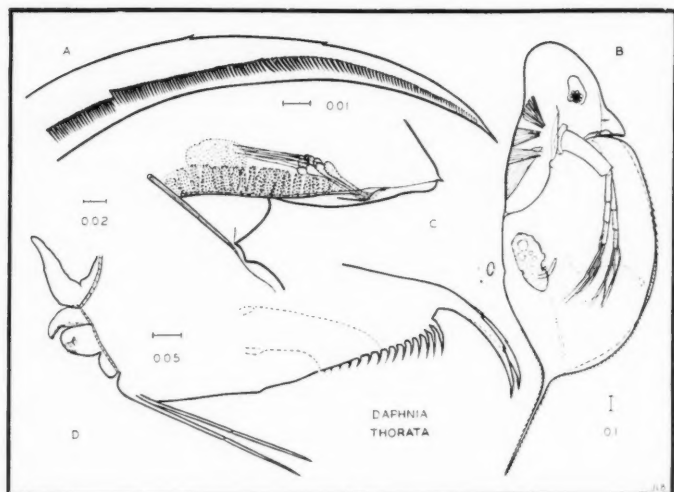


Fig. 2.—*Daphnia thorata* Forbes: A. Lectoparatype 1, right postabdominal claw, lateral aspect. B. Lectoholotype, mature female, lateral view. C. Lectoparatype 2, rostral portion of head in lateral view. D. Lectoparatype 1, postabdomen in lateral view.

Drawn with aid of camera lucida. Scales in millimeters. Arrow indicates artifact.

regions just posterior to the antennal base, then the sentence is more nearly applicable.

5. "The pigment speck is of moderate size, placed directly behind the eye, and much farther from it than from the posterior margin of head."

6. "The antennae are moderately stout, entirely smooth except for inconspicuous transverse rows of minute appressed hairs upon both peduncle and rami, and a row of short, tooth-like spinules at the distal end of each segment. The swimming hairs are rather slender, the second joint commonly decidedly shorter than the first."

The swimming hairs are very nearly of equal length.

7. "Fornices slight, arising above and a little behind the eye and terminating directly behind the antennae, above the bases of which they project but slightly."

8. "The intestinal coeca are short, not longer than the diameter of the eye, and extend directly forward."

CARAPACE

1. "The lower margin of each valve is set with the usual spinules almost to the beak, and the dorsal margin is similarly armed for a distance in front of the spine about equal to half the length of the latter."

Spinulation on dorsal margin extends this far in lectoholotype, somewhat farther in lectoparatype 1.

2. "The valves are marked off by fine lines into large quadrate meshes."
3. "The long and slender posterior spine is placed at or a trifle above the middle." "Length of spine somewhat variable, but commonly about equal to the depth of the shell."

ABDOMEN

1. "The dorsal abdominal processes rise separately, the two anterior, however, in immediate contact at their bases. The first of these is decidedly the longer, but the third process is distinct, although low."

Third process in lectotypes too large to be accurately described as "low."

2. "Anal setae two jointed, the second joint the shorter."

3. "The abdomen is regularly narrowed backwards, and the anal groove is provided with twelve to fifteen teeth on each side, commonly the latter number."

In mature females the number of anal teeth on each ridge is 14 to 18. The instar which may be adolescent usually has 12 or 13 teeth.

4. "The terminal claws are without accessory comb."

"Accessory comb" refers to the middle comb of the re-description, which, of course, is not lacking but has many teeth of small size.

DIAGNOSIS OF DAPHNIA THORATA Forbes

Dimensions: The smallest instar present, represent by three specimens, has a carapace just over half as long as that of lectoholotype, the largest specimen in the collection. The neck organ is obscure and this instar is probably, but not certainly, the second. In this instar CW and SS are about $\frac{2}{3}$ CL. HL is just over $\frac{1}{3}$ CL and HW just over $\frac{1}{2}$ CL.

The smallest ovigerous female has a carapace length of 1.3 mm. The other females of this size have empty brood pouches. They all have the proportions of lectoholotype.

Head: In smallest instar, helmet is less elongate, more broadly rounded than in lectoholotype (B, Fig. 2). Ventral margin of rostrum is straight rather than convex and apex is more blunt, less extended posteriorly so that posterior surface of rostrum is directed slightly anteriorly instead of curving posteriorly as in lectoholotype (compare C with B, Fig. 2).

Eye of moderate size, 75 to 95 microns in diameter in adult females.

Ocellus of adults, 10 microns across, between $\frac{1}{2}$ and $\frac{2}{3}$ the distance between posterior surface of eye and posterior surface of antennular ridge.

Antennae when folded against carapace extend posteriorly at least as far as flexure of abdomen at base of anal setae (cf. B, Fig. 2). In adults the tips of anal setae, when thorax is parallel to the long axis of carapace, do not reach posterior edge of carapace, although they do so in the smallest specimens.

Free border of fornix straight in lateral view, more or less parallel to body axis. Anterior end of fornix at level of middle of attachment of anterior antennal adductor. Posterior end well in front of mandibular articulation.

Structure of posterior surface of head dorsal to tips of antennules as in lectoparatype 2. Ventral to this point the structure is more variable, lecto-

paratype 2 representing the least development of rostrum, lectoholotype the greatest.

Carapace: Carapace somewhat broader relative to length in some adults than in lectoholotype. Extent of spinulation on each margin in all adults as in lectoholotype. Seldom does that on dorsal margin extend as far anteriorly as in lectoparatype 1.

Number of spinules on ventral edge of valve increases with size. In the smallest specimens there are 38-45, while animals of the size of the smallest ovigerous female have 48-54. The largest have 60-65. In all specimens the anterior spinules are 20-30 microns long, decreasing posteriorly to about 20 microns in the smallest females, to 15-20 in the young adults, to 10-15 in the largest individuals. Interspinule distance relative to spinule length shows the same pattern in all instars. The distance between anterior spinules is $1\frac{1}{2}$ to 2 times spinule length while that between posterior spinules is equal to, or slightly greater than, their length.

Spinules on dorsal margin small, 10-15 microns long.

The absolute length of shell spine increases from 0.55-0.6 mm. in the smallest specimens up to 1.0 mm. in the largest. Its length relative to that of carapace is, however, just over $\frac{1}{2}$ in the largest specimens, while it is about $\frac{2}{3}$ in the smallest. The angle which shell spine makes with body axis in all specimens is about as in lectoholotype.

Carapace is long relative to body proper as measured to base of anal setae, and its relative size increases with absolute size. In the smallest, body is about $\frac{4}{5}$ CL while in lectoholotype it is about $\frac{2}{3}$ CL.

Abdomen: First two abdominal processes in the adult female are contiguous at base but not united. First is about twice as long as second, both of same shape. Second, with hairs on tip and posterior surface. Third, shorter than second, broadly rounded apically, hairy. Fourth, low, with a few hairs on posterior surface (cf. D, Fig. 2).

Mature females have 14 to 18 anal teeth on each ridge, larger animals tending to have the higher numbers. Adolescent instar usually has 12 or 13 teeth although the number may range from 11 to 15. In the smallest instar present 11 is the usual number.

Three combs of fine teeth on postabdominal claw (cf. A, Fig. 2).

LOCALITY OF DAPHNIA THORATA

"Abundant in Swan and Flathead Lakes, Montana."

These two lakes, only twelve miles apart, are within the Flathead River System which is tributary to the Columbia.

DAPHNIA DENTIFERA Forbes

Fig. 3

Daphnia dentifera, S. A. Forbes, 1893, Bull. U. S. Fish Comm. 11: 242. *Daphnia angulifera* n.n., S. A. Forbes 1893, Bull. U. S. Fish Comm. 11: 218.

The most abundant entomostracan which Forbes discovered in the small lagoon or pond on the north side of Shoshone Lake was the species to which, in the description on page 243, he gave the name *Daphnia dentifera*. However, when describing the biota of this locality, he mentioned "a *Daphnia* of pale pink color, not seen by us before, and here described as *Daphnia anguli-*

fera," (p. 218). Although *angulifera* has page precedence, the mention of the pale pink color cannot be considered a description. The pink color which many species of pond *Daphnia* can acquire is usually due to haemoglobin dissolved in the body fluid and in the parthenogenetic eggs. Fox (1948) found that the three species which he studied, *magna*, *pulex* and *obtusa*, gained haemoglobin when living in water with little dissolved oxygen and lost it in well-aerated water. It is probable that many species of *Daphnia* might develop a pink coloration in a shallow, muddy lagoon such as that on the north side of Shoshone Lake. This coloration is therefore not of critical taxonomic significance. The name *Daphnia angulifera* Forbes, must be considered a *nomen nudum* and if, as appears, it is a synonym of *Daphnia dentifera* Forbes, it can have no status and is an evident *lapsus calami*.

Daphnia dentifera "had evidently been very much more abundant earlier in the season, as shown by the quantities of its summer eggs. These formed a film over many square feet of the surface and had been washed ashore in quantity as a scum-like deposit along the bank. A few of the females were still bearing ephippia." (p. 218)

DESCRIPTION OF TYPES

Lectoholotype (B, Fig. 3).—Mature female with three eggs in brood pouch lying on right side with dorsal margin lower than ventral edges of valves. Stained (boraxcarmine?). Shell spine broken off near base.

Dimensions: HL—0.365 mm., HW—0.75 mm., CL—1.15 mm., CW—0.92 mm., SS—broken, Antenna (to end of ventral ramus)—0.66 mm., Antenna (to tips of swimming hairs)—0.90 mm.

Head: Head with crest extending from margin overlying optic vesicle posteriorly to middle of attachment of antennal levator. Height of crest can be judged by distance between attachment of anterior antennal adductor and margin. Ventral margin concave with bottom of concavity opposite posterior edge of optic vesicle. Rostrum prominent, its ventral margin straight. Carina on posterior surface of head has its greatest depth dorsal to tips of antennules but has nearly the maximum depth between them, being distinctly higher than they are. Carina extends to tip of rostrum. Edge of carina dorsal to tips of antennules is scalloped. Its dorsal end sinks well below level of posterior surface of antennular ridge. Sensory hairs not visible (cf. H, Fig. 3). Dorsal margin of head from posterior end of crest to apex of head shield slightly concave.

Optic vesicle large, spherical, its greatest diameter, 220 microns. Eye large: its greatest diameter, 155 microns; its least, 120. Lenses deeply imbedded in pigment, their tangential diameter ca. 25 microns. Ocellus of moderate size, 10 microns in diameter, placed not quite halfway from posterior edge of eye to posterior surface of antennules.

Anterior end of fornix dorsal to posterior half of eye. Ridge into which fornix merges extends antero-ventrally ending just dorsal to anterior half of eye. Posterior end of fornix clearly anterior to mandibular articulation. Configuration of free edge of fornix and the degree to which it overlaps base of antenna cannot be judged from this specimen which is tipped with dorsal side lower.

Swimming hairs of antenna two-jointed but distal joints are so bent that measurement is impossible.

Carapace: Ventral margin more or less smoothly curved from opposite rostrum nearly to base of shell spine. Dorsal margin with bulge shortly behind apex of head shield, thence with slight convexity to base of shell spine (cf. B, Fig. 3). Entire dorsal margin free of spinules except for 3 just before base of shell spine. Spinules extend over posterior $\frac{2}{3}$ of ventral edge of valves. About 35 spinules on edge of each valve, those constituting anterior half of series longer (20-30 microns) and farther apart than those of posterior half.

Shell spine arises slightly dorsal to mid-line.

Abdomen: First abdominal process somewhat longer than second and third, glabrous (cf. D, Fig. 3). Second, with a few hairs on posterior surface. Third, about the same length as second but less tapering, is more hairy. Fourth is low mound, seemingly glabrous.

Anal ridge nearly straight, with a suggestion of a concavity near proximal end (teeth 8 to 10). Thirteen teeth on left side, 10 plus three tiny spinules on right. Length of teeth decreases sharply toward proximal end. Teeth 8 to 10 about $\frac{1}{3}$ length of first. Teeth smoothly tapering.

The two emarginations on ventral margin of postabdominal claw indistinct, even less distinct than is indicated in drawing (F, Fig. 3). Pectination consists of three combs of fine teeth all of about the same length. The middle comb extends distally to a point just beyond the more proximal ventral emargination.

Anal setae stout, two-jointed.

Lectoparatype 1 (A, Fig. 3).—Mature female with neither eggs nor embryos in brood pouch, lying on right side, with dorsal margin slightly higher than ventral edges of valves. Anterior part of optic vesicle collapsed (not indicated in drawing), and both shell spine and postabdominal claws broken off. Stained (boraxcarmine?).

Dimensions: HL—0.45 mm., HW—0.9 mm., CL—1.7 mm., CW—1.45 mm., SS—broken, Antenna (to tips of ventral ramus)—1.0 mm., Antenna (to tips of swimming hairs)—1.4 mm.

Head: Crest of same linear extent, although relatively lower, than in lectoholotype; margin similarly curved. Ventral margin of head concave but rostral portion slightly convex, with tip more bluntly rounded than in lectoholotype. Posterior surface of head as in lectoholotype except that carina is concave between tip of antennule and end of rostrum. Sensory hairs difficult to distinguish, but apparently there are about 7. Dorsal border of head between end of crest and apex of head shield nearly straight, more convex than concave.

Anterior end of fornix does not quite reach level of posterior edge of eye. Fornix broadest near posterior end, extending well over base of antenna.* Posterior end of fornix well anterior to mandibular articulation.

Swimming hairs two-jointed with both joints of terminal hairs of equal length. Terminal swimming hairs distinctly shorter than rami bearing them.

* The extent of overlap here is somewhat greater than in exactly lateral view, as specimen is tipped around body axis with dorsal side slightly higher.

Diameter of optic vesicle, 260 microns. Greatest diameter of eye, 180 microns; least, 155. Ocellus large, 15-20 microns in diameter, placed not quite halfway from posterior edge of eye to posterior surface of antennular ridge.

Carapace: Carapace almost circular in outline, with shell spine arising in midline, or possibly just ventral thereof.

Posterior two-thirds of ventral margins spinulate, with about 45 spinules. These are longest (ca. 30 microns) and farthest apart over anterior third of spinulate margin, with spinule length and interspinule distance decreasing posteriorly.

Posterior third of dorsal margin with spinules, 24 in a single series, which are 8 microns in length at anterior end to 18 at posterior end.

Abdomen: Tissues of dorsal abdominal processes shrunk away from cuticle as is indicated in A, Fig. 3. Processes of same shape as in lectoholotype, although first is relatively longer here, reaching almost twice the length of second or third. Second and third processes sparsely hairy, first and fourth glabrous.

Anal ridges straight, with 17 teeth on left side, and 14 on right. Teeth above base swollen in middle, tending to make body of tooth spindle-shaped.

Postabdominal claws broken off.

Anal setae stout, relatively short, with tips of each bent acutely suggesting a second articulation just before the tip.

Lectoparatype 2 (C, Fig. 3).—Immature female, possibly of about third instar, lying on left side, untipped. Stained (boraxcarmine?). Shell spine broken. Tissue along posterior border of head pulled away from exoskeleton. Notch in ventral edge of left margin.

Dimensions: HL—0.3 mm., HW—0.6 mm., CL—0.9 mm., CW—0.68 mm., SS—broken, Antenna (to end of ventral ramus)—0.54 mm., Antenna (to tips of swimming hairs)—0.78 mm.

Head: Less of optic vesicle touches margin than in lectoholotype because the adjacent anterior and ventral margins have larger crests. Base of crest indicated by line of muscle attachments. Crest produced into an angle with a wide base and a separate tip. The specific name is derived from presence of this angulate development of crest in young females and in males. Ventral margin of head as in lectoholotype except for crest developed below eye and somewhat more elongate rostrum. Posterior surface of head more curved than in lectoholotype, but otherwise similar. Dorsal margin posterior to crest slightly convex. Anterior end of fornix dorsal to posterior edge of compound eye, with ridge continuing anteriorly to level of middle of eye. Posterior end reaches mandibular articulation. Comparison of the nearly exact lateral view provided by this specimen with the appearance in a specimen tipped with dorsum lower (lectoholotype) and higher (lectoparatype 1) indicates that fornix projects laterally and is but little produced ventrally over the base of antenna. Swimming hairs difficult to measure as they curve out of plane of focus.

Diameter of optic vesicle, 170 microns. Greatest diameter of eye, 130

microns; least, 100. Lenses of same size as in lectoholotype. Ocellus slightly smaller than in lectoholotype but in same position.

Carapace: Dorsal margin of carapace nearly straight, only very slightly convex over anterior half. Shell spine makes slight angle with dorsal margin. Curvature of ventral edges much as in lectoholotype. Spinulation on dorsal margin confined to 5 spinules at base of shell spine. Spinulation on ventral edge of valve follows same pattern as in lectoholotype, with about 30 spinules. The anterior 15 spinules about 20 microns long, the last 15 decreasing from this length to about 12.

Abdomen: Tissue of dorsal abdominal processes pulled away from exoskeleton as indicated in drawing (C, Fig. 3). Second, third and fourth of same relative size and shape as in lectoholotype. First, however, relatively smaller, shorter than second.

Anal setae stout, as in lectoholotype. Anal ridges with concavity at level of teeth 7 to 9, concavity deeper on right side. On right ridge 12 teeth plus double spinule; on left 11, plus single spinule. Teeth of same relative size as in lectoholotype.

Postabdominal claw as in lectoholotype.

Lectoallotype 1 (G, Fig. 3).—Mature male, (right testis largely empty) lying on left side. Valves gaping with dorsal margin nearer to level of ventral edge of left valve. Stained (boraxcarmine?). Ventral edge of optic vesicle collapsed. Tissue pulled away from dorsal margin between posterior end of levator muscle and anterior part of carapace. Tip of shell spine broken off.

Dimensions: HL—0.23 mm., HW—0.43 mm., CL—0.71 mm., CW—0.5 mm., SS—broken, Antenna (to end of ventral ramus)—0.43 mm., Antenna (to tips of swimming hairs)—0.57 mm.

Head: Crest similar to, but larger than, that of lectoparatype 2. Crest produced into broad angle on margin between posterior antennal adductor and levator muscle attachments. Apex of angle serrate. Ventral margin nearly straight with slight convexity ventral to posterior half of eye and slight concavity immediately posterior thereto. Bluntly rounded tip of rostrum with lip-like projection between articulations of antennules with head proper. Detailed structure of antennules obscured by debris. Observable detail as in lectoallotype 2 (I, Fig. 3).

Antero-posterior diameter of optic vesicle somewhat greater than distance between its posterior edge and posterior surface of antennules. This diameter is 120 microns. Eye large: greatest diameter equals 100 microns; least, 80. Ocellus, 8 microns in diameter, $\frac{1}{3}$ the distance from posterior edge of eye to posterior surface of antennular ridge.

Anterior end of fornix dorsal to posterior edge of optic vesicle. Posterior end distinctly anterior to mandibular articulation. Free edge of fornix appears curved in this orientation. Swimming hairs two-jointed. Distal segment of terminal hairs longer than proximal.

Carapace: Valves rectangular in lateral view. Shell spine given off from postero-dorsal corner. Postero-ventral portion of valve broadly rounded. Antero-ventral portion produced as shoulder. Ventral margin sinuate and irregular over anterior two-thirds. Inner edge of ventral margin with long feathery hairs from shoulder to beginning of broad antero-ventral curve.

Spinules on outer edge of valve extend anteriorly to opposite the most posterior of long hairs on inner edge. Twenty to 25 long (25 microns), stout spinules of same length throughout series.

Abdomen: Exoskeleton of abdominal process swollen away from underlying tissue. Processes not drawn in E, Fig. 3 because of their distortion.

Anal ridges sinuate, more strongly so than those of females. Shallow bay anterior to anal ridges. Ten teeth on right ridge (long gap between proximal two) and 10 on left followed by two pairs of spinules. Most distal tooth on each side long and curved with succeeding teeth decreasing rapidly in length and curvature. Fifth and sixth tooth about $\frac{1}{3}$ the length of first (cf. E, Fig. 3).

Claw as in lectoholotype.

Anal setae slightly less stout than in females, with proximal segment relatively longer than distal as compared with female.

Lectoallotype 2.—Mature male, with right testis full of sperm, lying on right side. Stained (boraxcarmine?). Margin of head over optic vesicle collapsed, attachment of antennal levator muscle pulled away from exoskeleton. End of shell spine broken off.

Dimensions: HL—0.23 mm., HW—0.43 mm., CL—0.7 mm., CW—0.5 mm., SS—0.16 mm., Antenna (to end of ventral ramus)—0.45 mm., Antenna (to tips of swimming hairs)—0.68 mm.

Head: Ventral margin more nearly straight and rostrum more bluntly rounded than in lectoallotype 1. Otherwise margin is similar. Fornix here, seen in exact lateral view, has free edge concave, slightly less so than edge of lectoallotype 1 appears to be. Ocellus not quite halfway from posterior edge of eye to posterior surface of antennular ridge.

Antennule articulates with ventral end of antennular ridge (cf. I, Fig. 3). Proximal end of basal segment slightly wider when viewed laterally than distal end. Basal joint nearly straight (both joints are in plane of focus). About 7 sensory hairs on end of basal joint. Base of flagellum not raised above level of base of sensory hairs. Lateral hair about $\frac{1}{4}$ the length of basal joint from its distal end. Flagellum about as long as longest sensory hairs. At about middle flagellum decreases its diameter, tapering to a point. This tapered portion is curved, whereas thicker basal portion is straight.

Carapace: As in lectoallotype 1, but shoulders less prominent. Twenty-five spinules on edge of left valve.

Abdomen: Abdominal processes obscure. Twelve anal teeth on each ridge. The tenth on right side is double.

COMPARISON OF LECTOTYPES WITH ORIGINAL DESCRIPTION FEMALE

SIZE AND SHAPE

1. "Mature female 1.8 millimeters long by 1 millimeter deep."

The lectoholotype, a mature female is 1.6 mm. long and 0.92 mm. deep. Lectoparatype 1 is slightly over 2 mm. long and 1.45 mm. deep.

2. "This species is broad oval in form, has a long beak and a very large eye, a posterior spine placed high up, and in the male and young female a prominent angle on the dorsal outline between heart and eye."

HEAD

1. "The head is broadly rounded, with eye close to margin." "The lower margin of head is broadly concave, the beak produced, projecting as far as end of the sensory hairs."

Size of rostrum is variable, as a comparison of the two lectoparatypes will show (A, C, Fig. 3).

2. "The head is slightly crested, and the crest, extending backward to the heart, rises over the antennae in a prominent, nearly rectangular process, still more acute in the young, the tip of which is commonly truncate and bears two or three teeth inclining forward. In the egg-bearing female this process is reduced to a mere obtuse angle, or, in the last generation (that bearing the ephippium), disappears entirely. In young adults this dorsal angle is midway between the eye and the heart, but when fully developed it is on a line drawn from the anterior margin of the valve to the middle of the base of the antenna."

It is probably from Forbes' description that in female instars smaller than those represented in this collection, the angle of the crest more nearly resembles that of male (cf. G, Fig. 3). Although there is no indication in the lecto-holotype of the former presence of this angle, in other adults of the same size the serrate tip remains in evidence on the margin, or a low keel marks the site. In the largest females (which, of course, are not necessarily ephippial) there remains no indication of the angle.

3. "The fornices are short, rising above and behind the eye and extending backwards a little beyond the base of the antennae, where they form a prominent angle. Thence a slight lateral keel of the valve is continued downwards and backwards a distance about equal to the length of the fornix."

The "keel" of last sentence is the line of contact between head shield and valve, which is, indeed, slightly raised.

4. "The large eye, with numerous lenses is contained not more than twice in the distance from eye to beak, its diameter a little greater than that of the base of the antenna at its insertion."

In lectoparatype 2 where rostrum is elongate, the distance from edge of eye to apex of rostrum is slightly greater than diameter of eye.

5. "Pigment speck of moderate size, circular, immediately behind the eye and nearer to that than to the posterior margin of the head."

Correct except that in largest females ocellus is somewhat nearer posterior surface of antennules than it is to eye.

6. "The setae of the antennae are all two-jointed, the basal joint distinctly the longer."

The two joints of swimming hairs of terminal setae are of about equal length, or with basal joint the shorter.

CARAPACE

1. "The margins of the valves are set below and behind with slender thorns, as is also the posterior spine, these thorns extending forward a little distance upon the dorsal margin of the shell."

2. "The posterior spine of the carapace is long, slender, and weak, and

is commonly contained three or four times in the head and body without the spine."

The weakness of the spines is attested by the frequency of broken ones. In the two young females in which they are entire, the shell spines are just over $\frac{1}{4}$ CL.

3. "the surface of the snell is marked with quadrangular areolations."

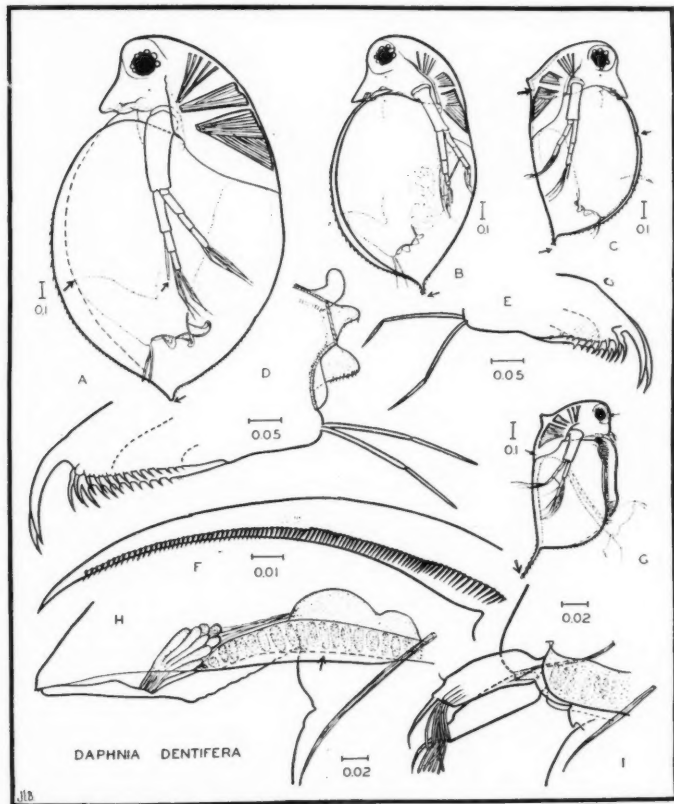


Fig. 3.—*Daphnia dentifera* Forbes: A. Lectoparatype 1, old female, in lateral view. B. Lectoholotype, mature female, in lateral view. C. Lectoparatype 2, immature female, in lateral view. D. Lectoholotype, postabdomen, in lateral view. E. Lectoallotype 1, postabdomen, in lateral view. F. Lectoholotype, left postabdominal claw, lateral aspect. G. Lectoallotype 1, mature male, in lateral view. H. Lectoholotype, rostral portion of head, lateral view. I. Lectoallotype 2, male, rostral portion of head in lateral view.

Drawn with aid of camera lucida. Scales in millimeters. Arrows indicate artifacts.

ABDOMEN

1. "The first and second dorsal abdominal processes are about equal in length and arise in immediate contact, the anterior turning forward and the posterior backward."

This describes the processes in most adults, except the very largest in which the first process is distinctly the longer (cf. B, D, Fig. 3).

2. "The curved spines bordering the anal furrow are thirteen in number."

Thirteen and 14 are the usual numbers of anal teeth in adults, although the largest may have up to 17.

3. "the caudal claws are without accessory teeth."

This statement means, of course, that the teeth in all the combs are fine and numerous.

MALE

SIZE AND SHAPE

1. "Mature specimen 1 millimeter long by 0.5 millimeter deep." "The male of this species is smaller than the female";

The males are considerably smaller than the females, those mature males in this collection being slightly under 1 mm. in length of head and carapace.

HEAD

1. "the head is smaller and narrower [than in the female], the form is more nearly elliptical, and the dorsal angle is as prominent as in the young female, and commonly bears obscure teeth at the tip." "The head is subquadrate, with rounded angles."

2. "The very large eye is at the extreme front of the head, its diameter greater than the distance between the eye and the posterior margin of the head."

3. "Below, the head is straight; the anterior antennae are not especially prominent and the terminal spine is inconspicuous."

As flagellum of antennule is about the length of sensory hairs it is relatively inconspicuous.

CARAPACE

1. "The posterior spine is like that of the female, long and slender and dorsally placed."

Apparently correct although it is difficult to comment on the spine length as most spines are broken.

ABDOMEN

1. "The abdomen is without dorsal process."

DIAGNOSIS OF *DAPHNIA DENTIFERA* Forbes

FEMALE

Dimensions: The smallest female in the collection is only slightly smaller than lectoparatype 2 (C, Fig. 3) and only one is a bit larger than lectoparatype 1 (A, Fig. 3). Lectoparatype 2 probably pertains to the third or fourth instar at least, as mature males are smaller than it is. Neonatae of the two sexes are usually of the same size.

Head: Margin of head produced into a keel or crest except where optic vesicle is in contact with cuticle. Variation in extent of crest apparent on

comparison of lectotypes. Fornix widest near posterior end. Anterior end of fornix continues into a ridge which runs to the crest immediately anterior to the eye.

When antennae are folded against carapace, tips of swimming hairs extend as far as first abdominal process.

Variation in extension of rostrum apparent from drawings of lectotypes. Configuration of posterior surface of head constant (cf. H, Fig. 3).

Carapace: Change in shape of carapace with size is apparent from drawings.

Pattern of spinulation on both margins of the carapace is similar in all of females except two largest. Animals of the size of lectoparatype 2, i.e. the smallest, have 27 to 30 spinules on ventral margin. In females the size of lectoholotypes there are 33 to 35 to base of shell spine. There are about 27 spinules on ventral margin to the place where curve of margin changes near base of shell spine. Additional spinules have apparently formed at base of shell spine. Anterior spinules in the smaller animals are about 20 microns long, decreasing somewhat posteriorly. Spinules in the smaller mature measure 20-30 microns at the anterior end, decreasing to $\frac{1}{2}$ that length at base of shell spine. Distance between spinules is about $1\frac{1}{2}$ times spinule length anteriorly, decreasing to the equal of spinule length at posterior end of series. There are 2 to 5 spinules on dorsal margins of smallest females and 6 on small mature females. On the other hand the largest two have 24 and 49 respectively, extending over posterior third and half of their respective dorsal margins. In addition to this striking difference, there are 46-48 spinules on ventral edge of valves of these two large specimens. Spinules are about as long in these as they are in the smaller adults. It seems unlikely that the younger instars through which these large individuals passed had as few spinules on each margin as do the lectoholotype and lectoparatype 2.

Shell spines are apparently very fragile as they are unbroken on only two females. Both of these are about the size of lectoparatype 2 and have spines about 0.25 mm. long.

Carapace as long as body to base of anal setae in smallest specimens, slightly longer in the larger.

Abdomen: First, second and third abdominal processes are of much the same length in small adults (cf. B, D, Fig. 3), although in very large females, first is as much as twice as long as second. Second and third processes sparsely hairy; the fourth, a low mound, with a few inconspicuous hairs.

Dorsal margin of postabdomen very nearly straight from base of anal setae to first (distal) anal tooth. Anal ridge straight or with shallow concavity near proximal end.

The number of anal teeth in mature females varies from 10 to 17, with 13 or 14 being the usual number for small adults. The largest specimens usually have more. The smallest specimens have 11 or 12 teeth.

Anal setae stout.

Teeth in all three combs of postabdominal claw fine, of about same size (F, Fig. 3).

MALE

Dimensions: All males in the collection of same size as lectotypes.

Head: As in lectotypes. (cf. G, I, Fig. 3).

Carapace: Ventral edge of valves of some specimens much more like female than like lectoparatype (G, Fig. 3). Twenty to 30 long spinules on outer rim of ventral edge of valves. Two to 4 spinules at posterior end of dorsal margins.

Abdomen: All abdominal processes inconspicuous, third (first wanting) is most prominent.

Dorsal margin of postabdomen sinuate with concavity near anterior (proximal) end of anal ridge and a shallow (often less deep than in drawing E, Fig. 3) bay anterior to anal furrow.

Ten to 12 anal teeth on each ridge.

Postabdominal claw as in female.

LOCALITY OF *DAPHNIA DENTIFERA*

"Pool near Shoshone Lake, Yellowstone Park."

Forbes gives the following descriptions of the type locality in the discussion of the collections:

"Near the mouths of the larger stream, ponds or small lagoons occur, connected with the lake at high water, and in mid-summer thick with vegetation and swarming with animal life." (p. 215.)

"Our camp was placed in a small grove on the flat at the mouth of Heron Creek, where we had at hand the creek itself and a small, very weedy and very muddy lagoon, filled earlier with overflow waters but then disconnected from the lake." (p. 215.)

"The small brown lagoon or pond already mentioned as occurring near the lake was an example of a kind quite common along the lake borders of this region. It is separated from the lake itself only by a narrow strip of beach, and is largely filled with pond lilies (*Nuphar*), grass, algae, and the like, which grow out of a deep, soft ooze." (p. 218.)

It is noteworthy that *dentifera* was abundant in the lagoon, yet not taken in the body of Shoshone Lake itself.

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A Study of the Population of Insects Emerging as Adults from the Dundas Marsh, Hamilton, Ontario, During 1948¹

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The first recorded studies of insects from the Dundas Marsh concern the phalaenid moths, *Arzema obliquata* and *A. diffusa*, whose larvae drill in the leaves of aquatic plants. Moffat (1888, 1888a) reported collecting *A. obliquata* from reeds and stumps in the vicinity of the marsh and Johnston (1889) recorded the occurrence of both of these species in his collections. Moffat (1889) also reported collecting *A. obliquata* and *Nonagria fodians* from a cat-tail, *Typha* sp. In 1946 a few species of insects were collected about the marsh and in 1947 a project was undertaken to determine the times of first and last emergence and the period of maximum emergence of various species which emerge as adults from the water. These studies are discussed by Judd (1947, 1949, 1949a, 1950a). In 1948 a study was made of the population of insects emerging from the marsh from March to November, the present paper being a report on this project.

ACKNOWLEDGMENTS

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DESCRIPTION OF MARSH

The Dundas Marsh, lying along the northern limits of the city of Hamilton, Ontario, has an area of about 700 acres (Fig. 1). During the past it has received a variety of names. Father Hennepin, missionary and explorer, visited the region early in the seventeenth century and named it "Little Flanders." It was later named "Coote's Paradise" after a Captain Coote of the 8th Regiment of Foot in the garrison at York, who hunted water-fowl in the marsh. The name "Jubilee Sanctuary" was applied to the marsh to com-

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² At the time, Assistant Professor of Zoology, McMaster University, now Associate Professor of Zoology, University of Western Ontario.

memorate the jubilee year of King George V in 1935. It is now part of the properties of the Royal Botanical Gardens.

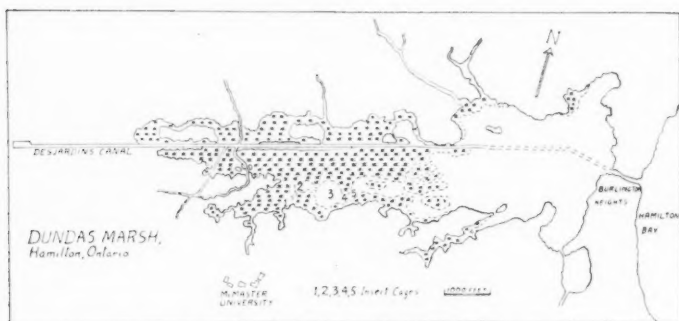


Fig. 1.—Map of Dundas Marsh showing locations of cages.

The marsh lies in the Dundas Valley which is bordered on its northern and southern limits by the Niagara Escarpment, and several streams that pour over the escarpment feed the waters of the marsh. In its original condition it emptied into Hamilton Bay by an outlet at its northeastern end. In 1827 the construction of the Desjardins Canal was begun and it was opened for traffic in 1837. The canal extends eastward from a turning basin in the town of Dundas for a distance of about three miles and has access to Hamilton Bay by a cut through Burlington Heights which separates the marsh from the bay. With the increase in importance of Hamilton as a port and railway center in the latter part of the nineteenth century the Desjardins Canal fell into disuse and today is navigable only by canoe or small boat.

At the eastern end of the marsh is open water which in 1948 comprised about one-third of the total area of the marsh. The remainder of the area supports a heavy growth of aquatic and marsh-dwelling plants (Judd, 1950). The predominant plant in the central part of the marsh is the Old World Manna Grass, *Glyceria maxima* (Hartm.) Holmb. (Dore, 1947). *Typha latifolia* L., also forms extensive stands throughout the marsh and various submerged plants grow in quiet stretches of water extending westward from the open water.

METHODS

The use of traps set out on bodies of water to collect insects emerging from the surface was introduced by Needham (1908) in 1905 when he made quantitative studies of the population of insects in a lake in New York. The same method was used by Adamstone and Harkness (1925) in conducting studies of bottom organisms in Lake Nipigon, Ontario. The cage was moved about from one location to another and emerging midges were trapped. Scott and Opdyke (1941) used floating cages covering one square meter or one-quarter of a square meter of surface on Winona Lake in Indiana. They

visited the cages twice a day and removed insects from them. Miller (1941) studied the chironomid population of Costello Lake, Ontario, using five floating traps anchored at specified points on the lake. Each trap was made of cotton stretched on a frame of wood and wire covering four square feet of surface. In his investigations on the insects of rapid streams Ide (1940) used screen-covered traps set on the rocks or over the bottom of the stream.

To carry out studies of insects emerging from the water of the Dundas Marsh in 1948 five cages were used (Fig. 2), located at the same positions as in 1947 (Judd, 1949, 1949a). They were placed at selected points on the marsh (Fig. 1) in water of differing depths and in regions supporting various growths of vegetation. The wooden frame of each cage was 36 inches long, 30 inches wide and 36 inches tall. The top and four sides were covered with No. 16 copper screening. The bottom of the cage was open. Along the upper part of each of the 36-inch sides was a door of dimensions 32 inches by 15 inches, hinged at the bottom to allow the collector access to the inside of the cage. Each door was held shut by hooks at its top. Each cage was set securely over four 2 inch by 2 inch posts driven firmly into the bottom of the marsh so that the lower border of the cage was about one foot below the surface of the water.



Fig. 2.—Cage 1, August 26, 1948 (water depth—16 inches).

The cages were visited by canoe between 9:30 a.m. and 11:30 a.m. (in a few cases between 2:00 p.m. and 4:00 p.m.) daily, or as frequently as possible during the week. The depth of the water was read from a scale (inches) attached to the side of the cage. The maximum and minimum temperatures of the water for the previous 24-hour period at the bottom of the marsh were taken at each cage with a Taylor Six's maximum-minimum thermometer. The thermometer was attached to the cage by a chain and was drawn up to the surface to be read.

After the depth and temperatures of the water at a cage had been recorded the insects were collected from the cage. The canoe was drawn up alongside the cage and one of the doors was opened. Large insects (dragonflies, damselflies, etc.) were captured by hand and were put in a cyanide jar. Small insects (midges, etc.) were sucked into a jar by means of an aspirator and then transferred to the cyanide jar. Dead insects lying on the surface of the water were scooped up with a small strainer and were placed in preservative. Collections from the different cages were kept separate. On return to the laboratory representative specimens were pinned and labelled (date, name of collector, number of cage) and the remaining specimens were placed in preservative in shell vials, specimens from each of the five cages being kept separate. The number of specimens of each species in a daily catch, from each cage, was determined and recorded. All specimens, pinned and preserved, are retained in collections at McMaster University except series kept by specialists who examined and identified the insects.

On March 16 the marsh was covered with ice except for a small area adjacent to the outlet through Burlington Heights. After this date a thaw set in and by March 21 the open areas of the marsh were free of ice, while in the area in which the cages were to be set out, the ice was still solid and covered with several inches of water. By March 31 the area was free of ice, except close to the shore, and on that date Cages 2, 3, 4 and 5 were set in position. At the prospective site of Cage 1 the bottom of the marsh was still frozen. By April 5, thawing had softened the bottom of the marsh at this point sufficiently to allow stakes to be driven in and Cage 1 was set in position.

Cage 1 was removed from the marsh on October 18 when thin shell ice had formed over the water at this location during the previous night. On October 22 ice one-quarter inch thick formed over the water from the shoreline to the vicinity of Cage 2. On succeeding days warm weather prevented the formation of ice and Cages 2, 3, 4 and 5 were removed from the marsh on October 22, 25, 27 and 29 respectively. The thermometers were left attached to the stakes until November 20 and temperatures and depths of the water were recorded till that date. On December 1 the marsh was free of ice and on succeeding days till December 8 shell ice formed during the night and melted during the day. On December 9 the marsh was frozen over with ice one-half inch thick except in the area of open water and on December 11 the whole marsh was covered with ice one and a half inches thick except in the outlet through Burlington Heights.

DATA ON CAGES

Cage 1.—In operation over period April 5–October 18; located 20 feet from shore (Fig. 1). Plants in cage: *Typha latifolia* (L.) (predominant), *Myriophyllum verticillatum* L. (predominant), *Spirodela polyrhiza* (L.) Scheld., *Lemna minor* L., *Wolffia columbiana* Karst., *Ceratophyllum demersum* L., *Anacharis canadensis* (Michx.) Planchon, *Ricciocarpus natans* (L.) Corda.

Cage 2.—In operation over period March 31-October 22. *Plants in cage:* *Utricularia vulgaris* var. *americana* Gray (predominant), *Myriophyllum verticillatum* L., *Spirodela polyrhiza* (L.) Scheld., *Lemna minor* L., *Wolffia columbiana* Karst., *Ricciocarpus natans* (L.) Corda.

Cage 3.—In operation over period March 31-October 25. *Plants in cage:* *Ceratophyllum demersum* L. (predominant), *Spirodela polyrhiza* (L.) Scheld., *Lemna minor* L., *Wolffia columbiana* Karst.

Cage 4.—In operation over period March 31-October 27. *Plants in cage:* *Nymphaea odorata* Ait. (predominant), *Potamogeton pectinatus* L., *Ceratophyllum demersum* L., *Spirodela polyrhiza* (L.) Scheld., *Lemna minor* L., *Wolffia columbiana* Karst.

Cage 5.—In operation over period March 31-October 29. *Plants in cage:* *Ceratophyllum demersum* L. (predominant), *Potamogeton pectinatus* L., *Spirodela polyrhiza* (L.) Scheld., *Lemna minor* L., *Wolffia columbiana* Karst., *Ricciocarpus natans* (L.) Corda.

The depth of the water at the five cages reached a maximum at the end of May (Fig. 9) and maintained a high level during June. Thereafter the level fell gradually during the summer and fall and by November 8 the marsh was dry at the site of Cage 1. On April 5 when all cages had been set in position the water depths were 22, 26, 37, 48 and 41 inches at Cages 1, 2, 3, 4 and 5 respectively. At the end of May when maximum depths were recorded the readings were: Cage 1—28 in. (May 27); Cage 2—35 in. (May 26); Cage 3—47 in. (May 27); Cage 4—58 in. (May 27); Cage 5—51 in. (May 27).

RELATION OF TEMPERATURE OF WATER TO EMERGENCE OF INSECTS

The maximum and minimum temperatures of the water over 24-hour periods at the bottom of the marsh were recorded at each cage. These temperatures were averaged and the averages for each day were tabulated. The first readings were taken on March 16 when the marsh was frozen and water in small pools on the ice had a temperature of 0°C. Following thawing, temperatures of the water rose rapidly and the maximum average temperatures were attained on July 14 (Cage 1—22.5°C.; Cage 2—22.2°C.; Cage 3—24.2°C.; Cage 4—24.4°C.; Cage 5—24.2°C.) (Fig. 8). Thereafter the temperatures fell irregularly during summer and fall. Readings of temperature were continued till November 20. The total accumulation of day-degrees at each cage was arrived at by summing the average daily temperatures from

| Cage | Day-degrees | Difference from average | Percentage difference |
|---------|-------------|-------------------------|-----------------------|
| 1 | 3568 | —153 | —4.1 |
| 2 | 3596 | —125 | —3.4 |
| 3 | 3792 | 71 | 1.9 |
| 4 | 3809 | 88 | 2.4 |
| 5 | 3840 | 119 | 3.4 |
| Average | 3721 | | |

March 16 to November 20. These accumulations are tabulated as follows:

The increase in the average accumulation of temperature at the five cages from March to November is represented in Figure 8. The accumulations of temperature differ little from one cage to another owing to the shallowness of the water at the five cages and consequent lack of thermocline. The accumulations were calculated in the same way as those calculated by Miller (1941) in his study of the Chironomidae of Costello Lake in Algonquin Park. He trapped insects in five floating tent-traps, Number 1 being in water one meter deep and the others in water 3 or more meters deep. The thermocline in the lake was at a level from four to seven meters. The accumulation of day-degrees at Miller's cage 1 was 3,900 in 1938, a temperature of 0°C. being recorded on April 29 and the temperature records being maintained till November 20. The accumulations at his other cages were considerably less, ranging down to 770 at a cage in water 17 meters deep. The accumulation at Miller's Cage 1 in 1938 (3,000 day-degrees) approximates the value obtained in the Dundas Marsh in 1948 (3,721 day-degrees) when it is considered that 342 day-degrees had accumulated in the marsh on April 29, 1948, and the water temperature was still 0°C. in Costello Lake on the same date in 1938.

The curves in Figure 10 represent the numbers of insects of known species that emerged daily from the marsh and the number of species occurring in these collections. Peaks of emergence showed in April, in the first week of June and in the middle of July. The day of maximum emergence was August 4 owing largely to the great numbers of the midge, *Pelopia punctipennis*, that emerged on that day (Fig. 4E). The maximum number of species, 19, emerged on July 15, one day after the temperature reached its maximum at the five cages, indicating that the seasonal variation in the emergence of numbers of species is correlated directly with changes in temperature. Miller (1941), in his studies of emergence of midges from Costello Lake, found that the number of species emerging reached a maximum in the week of July 6-12, 1938, and that the highest temperatures occurred also in that week.

The average accumulation of day-degrees during the season is plotted in Fig. 8. From this graph the number of day-degrees accumulated up to the date of maximum emergence of each species of insect has been determined. These figures are included in the discussion of the times of emergence of each species in the section entitled "Account of species collected."

PRODUCTION OF ADULTS

In a population of larvae and nymphs existing on an area of the bottom of a marsh or on the plants growing from it some insects are destroyed by predators or parasites, some succumb to changes in the physical environment, some fail to complete emergence from the pupal or nymphal skin successfully while others achieve full emergence. The numbers of insects emerging from a given surface of water do not, therefore, represent the total insect productivity of the bottom of the marsh beneath it, but rather only those which successfully emerge. In Table 2 figures are presented to show the amounts and percentages of the crop of adults produced at the different cages in the

Dundas Marsh. It is assumed that each wasp that emerged was a parasite on a single larva of its host species.

The area of water surface covered by each cage was 36 inches by 30 inches (1,080 sq. inches or 7.5 sq. ft.), so that the total area from which emerging insects were collected was five times this area, i.e., 37.5 sq. ft. Over the whole period in which the adults were trapped 15,338 insects emerged, an emergence of 409 per sq. ft. Some sources of error will affect the reliability of this figure. It is likely that some insects were missed in the process of making the daily collections and that some successfully escaped from the cages. Also the presence of the four sturdy stakes at each cage probably attracted into the area covered by the cage adult insects that lay eggs on solid objects beneath the water as well as larvae that require a solid surface on which to pupate and nymphs that climb a vertical support before producing adults.

The numbers of insects of the various orders that emerged in the cages are shown in Table 2. Adult Diptera constituted the large majority of the emergents (87.1 percent) and most of these Diptera (92.5 percent) were midges. Most of the crane-flies (Tipulidae) that emerged (4.3 per cent of the Diptera) did so in the shallower water at Cages 1 and 2 among stands of cat-tail. A few biting midges, Heleidae, (= Ceratopogonidae), 1.4 percent of the Diptera, emerged and were well distributed throughout the cages. Very few mosquitoes (0.1 percent) appeared. Other families of Diptera were represented by a few individuals comprising 1.7 percent of the total. The mayflies (Ephemeroptera) comprised 9.9 percent of the total emergents and most of them appeared in the three Cages 2, 3, and 5 in deeper water, more than half emerging in Cage 5. Odonata constituted a small percentage (1.5 percent) of the total emergents. Dragonflies of the family Libellulidae emerged mainly in Cages 1 and 2 in shallow water. The large aeschnid dragonfly, *Anax junius*, appeared in all cages. Two of the damselflies, *Lestes rectangularis* and *Enallagma ebrium*, emerged mainly in Cages 1 and 2 while the third, *Ischnura verticalis*, appeared only in Cages 3, 4 and 5. The caddis flies (Trichoptera) were represented by 75 adults that appeared in all cages except No. 1, and the five species of moths (0.9 percent) emerged in all cages. The ichneumonid parasites also appeared in all cages and were probably parasitic on lepidopterous larvae, while the single species of chalcid wasp emerged only in Cages 1 and 2 and was very likely parasitic on the soldier fly, *Odontomyia vertebrata*.

The most productive of the cages was No. 4 in which almost half (45.7 percent) of the total number of insects emerged. The midges predominated in this cage, as is in the others; more than half the catch was composed of the midge, *Pelopia punctipennis*. Cage No. 5 yielded 24.0 percent of the total numbers of insects with the midges predominating. These two cages, then, yielded slightly more than two-thirds (69.7 percent) of the total number of insects, owing largely to the concentration of midges in those areas. The other three cages captured lesser numbers of insects but in them some groups predominated, as the Tipulidae in Cage 1, the Zygoterous Odonata in Cages 1 and 2 and several families of Diptera, represented by a few specimens in Cage 2.

ACCOUNT OF SPECIES COLLECTED
EPHEMEROPTERA

BAETIDAE

Caenis simulans McDunnough.—Emergence period: May 29-September 17, maximum July 20 (124 insects; 1,842 day-degrees; Fig. 3A). The majority of these insects emerged from Cages 3, 4 and 5 in open water away from the shore (Table 1). The species was trapped in the cages in 1947 (Judd, 1949).

Callibaetis fluctuans Walsh.—Two mayflies were trapped on September 15, one in

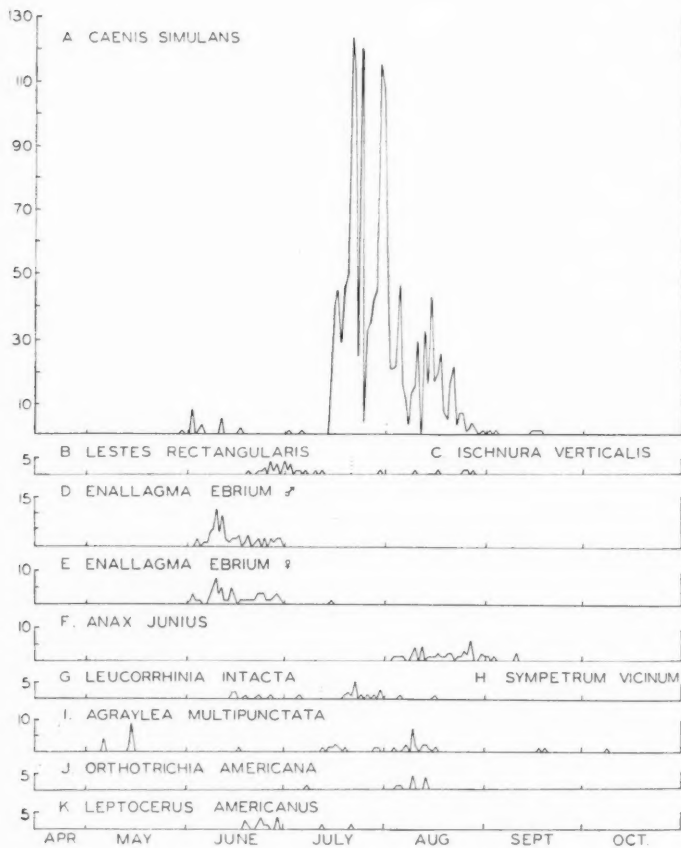


Fig. 3. (A-K).—Periods of emergence of adults of Ephemeroptera, Odonata and Trichoptera.

Cage 4 and one in Cage 5 (Table 1). The species was captured in 1947 at the end of August and in September (Judd, 1949).

ODONATA

LESTIDAE

Lestes rectangularis Say.—Emergence period: June 19-July 12, maximum June 26 (4 insects; 1,307 day-degrees; Fig. 3B). The majority of these insects emerged in Cages 1 and 2, close to shore (Table 1). This species appeared in 1947 in June and July (Judd, 1949).

COENAGRIIDAE

Enallagma ebrium (Hagen).—Males: Emergence period: June 3-29, maximum June 9 (11 insects; 972 day-degrees; Fig. 3D).

Females: Emergence period: June 1-July 15, maximum June 9 (8 insects; 972 day-degrees, Fig. 3E).

More than half of the insects emerged in Cage 1 (Table 1), indicating that the nymphs of this species inhabit shallow, weed-choked stretches of water. Walker (1941) records that this damselfly frequents "still marshy waters." In 1947 the species emerged in June and July (Judd, 1949).

Ischnura verticalis (Say).—Three males and three females emerged in the cages, the first appearing in Cage 5 on July 29 and the last in Cage 3 on August 27 (Fig. 3C). They emerged in Cages 3, 4 and 5 (Table 1). In 1947 this species appeared in July and August (Judd, 1949). Walker (1941) reports that "the majority appear in early June and there is another lower peak of emergence in the second half of August."

AESCHNIDAE

Anax junius (Drury).—Emergence period: August 3-September 10, maximum August 27 (6 insects; 2,624 day-degrees; Fig. 3F). Walker (1941) records that the species occurs in the second half of August and in September. On April 19 and 21 adults were seen in flight and settling on sunny paths near the marsh. They were probably adults returning from the south (cf. Walker, 1941). In 1947 this dragonfly was trapped during August and September (Judd, 1949).

LIBELLULIDAE

Libellula quadrimaculata L.—One specimen emerged in Cage 1 on June 17 (Table 1). In 1946 the species was collected in June (Judd, 1949).

Sympetrum vicinum (Hagen).—Emergence period: July 19-August 16, maximum July 22 (5 insects; 1,887 day-degrees; Fig. 3H). The majority of these dragonflies emerged in Cages 1 and 2 and none appeared in Cage 5 (Table 1), indicating that the species frequents shallow waters. Walker (1941) points out that this insect inhabits the marshy borders of permanent ponds. Emergence occurred in cages during July and August in 1947 (Judd, 1949).

Leucorrhinia intacta Hagen.—Emergence period: June 14-July 5, maximum June 15 (2 insects; 1,089 day-degrees; Fig. 3G). The greatest number of this species emerged in Cage 2 (Table 1). In 1947 adults appeared at the end of June (Judd, 1949).

TRICHOPTERA

PSYCHOMYIIDAE

Polycentropus flavus (Banks).—A single specimen emerged in Cage 4 on July 8 (Table 1). Ross (1944) records that this species has been collected previously in Ontario.

HYDROPTILIDAE

Agraylea multipunctata Curtis.—Emergence period: May 5-October 8, maximum May 14, August 9 (9, 7 insects; 522, 2,253 day-degrees; Fig. 3I). This caddis fly emerged mainly in Cages 3, 4 and 5 in open water (Table 1). In 1947 collections were made in the middle of May (Judd, 1949). Ross (1944) reports collections from other localities in Ontario.

Oxyethira verna Ross.—A single specimen emerged in Cage 4 on August 9. This collection represents an extension in the known range of the species, for Ross (1944) says of this insect "the only record outside of Illinois is from New Brunswick indicating a wide but probably local range."

Orthotrichia americana Banks.—Emergence period: July 7-August 13, maximum August 9 (4 insects; 2,253 day-degrees; Fig. 3J). All the insects emerged in Cages 3, 4 and 5 (Table 1).

LEPTOCERIDAE

Leptocerus americanus (Banks).—Emergence period: June 18-July 21, maximum June 23 (3 insects; 1,245 day-degrees; Fig. 3K). All the insects emerged in Cages 3, 4 and 5 (Table 1). In 1947 a single specimen was trapped in June (Judd, 1949).

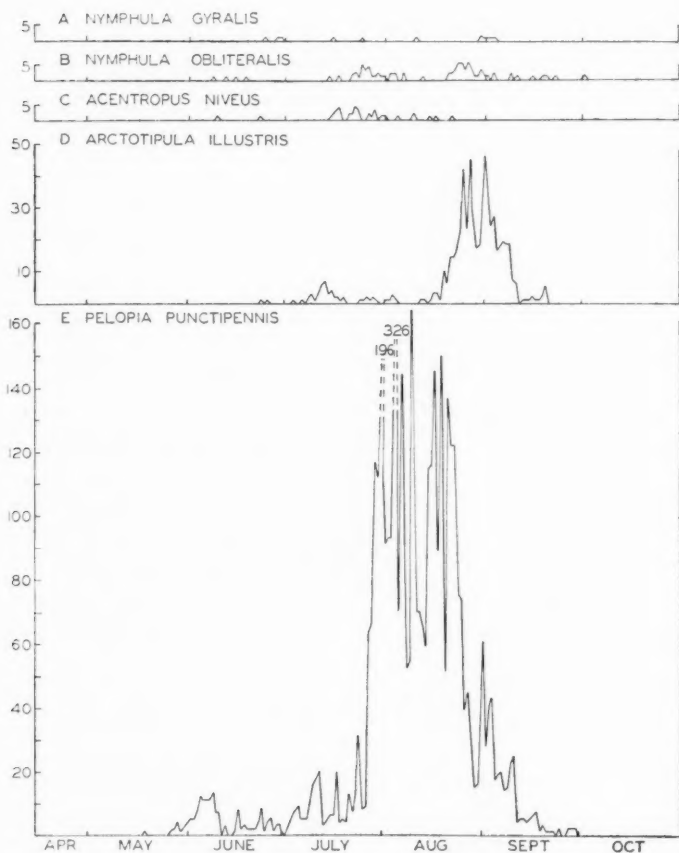


Fig. 4 (A-E) —Periods of emergence of adults of Lepidoptera and Diptera.

LEPIDOPTERA

PYRALIDAE

Nymphula gyralis Hlst.—Emergence period: June 24-September 3, maximum August 30 (2 insects; 2,693 day-degrees; Fig. 4A). This species emerged in Cages 3, 4 and 5 (Table 1). In 1947 the moths were trapped in July, August and September (Judd, 1949).

Nymphula oblitalis Walker.—Emergence period: June 8-October 1, maximum July 24, August 23 (5, 5 insects; 1,930, 2,536 day-degrees; Fig. 4B). The moths emerged in all cages, mostly in 1, 2 and 3 (Table 1). In 1947 they appeared in July, August and September (Judd, 1949). Scotland (1940) records that the larva of this species feeds on and makes cases of *Lemna minor* and Hart (1896), referring to it as *Hydrocampa oblitalis*, says that the favorite home of the larva is among the floating leaves of *Potamogeton natans*, the imagos becoming most abundant in August and September. *Lemna minor* was present on the surface of the water in all cages and seven species of *Potamogeton* grow in the marsh (Judd, 1950). Some of these plants were possibly food for the larvae of *Nymphula oblitalis*.

Nymphula icciusalis Walker.—A single specimen emerged in Cage 5 on July 19 (Table 1). In 1947 this moth was captured in June and August (Judd, 1949). Berg (1949, 1950) and Welch (1916) record that the larval and pupal stages are passed on *Potamogeton natans*. In the Dundas Marsh the young stages possibly inhabit some of the *Potamogeton* that grow in the marsh (Judd, 1950).

Nymphula badiusalis Walker.—One moth emerged in Cage 5 on August 5 (Table 1). Berg (1949, 1950) records that the young stages develop on five species of *Potamogeton* one of which, *P. zosteriformis*, grows in the Dundas Marsh (Judd, 1950). Brodie and White (1883) record this species from Ontario under the name *Oligostigma albalis* Rob.

Acentropus niveus Olivier.—Emergence period: June 9-August 21, maximum July 17 (4 insects; 1,776 day-degrees; Fig. 4C). The largest numbers appeared in Cages 3 and 5 (Table 1) in which the predominant plant was *Ceratophyllum demersum*. This species was collected in the marsh in 1947 (Judd, 1947, 1949) in larger numbers than in 1948. It occurs commonly in Europe where the larva is known to feed on *Anacharis canadensis* (Michx.) Planchon, *Ceratophyllum demersum* L. and *Potamogeton perfoliatus* L. (Judd, 1950b). These three plants grow in the Dundas Marsh (Judd, 1950) and probably form part of the food supply of the larvae.

DIPTERA

TIPULIDAE

Arctotipula illustris Doane.—Emergence period: June 23-September 19, maximum August 31, (46 insects; 2,715 day-degrees; Fig. 4D). About two-thirds of these insects emerged in Cage 1, indicating that the larvae inhabit shallow water among cat-tails (Table 1). In 1947 the flies emerged from July to September (Judd, 1949). Alexander (1919), referring to it as *Strygeropsis fuscipennis* Loew, records that the species is a characteristic inhabitant of marshy situations and appears on the wing in July and August, and the same author (Alexander, 1920), referring to it as *Prionocera fuscipennis* (Loew), reports that larval and pupal skins have been found among *Sparganium* stems and in a cat-tail swamp at Ithaca, New York.

Limonia moniliformis (Doane).—Two flies emerged in Cage 1, one on September 19, and the other on October 15, and one emerged in Cage 3 on July 19 (Table 1). Alexander (1919), referring to this fly as *Dicranomyia moniliformis* Doane, records that it has been taken on Long Island, New York.

Helius flavipes (Mgt.).—A single fly emerged in Cage 1 on August 17 (Table 1). Johanssen (1934) reports that larvae and pupae have been found in cat-tail swamps. Alexander (1919) refers to the species as *Rhamphidia flavipes* Macq. and records finding it in organic mud in swamps in New York State. He reports (1920) that it is characteristic of cat-tail swamps and has been reared from leaves of *Sparganium* and that its larvae were associated with the larvae of *Prionocera fuscipennis* (i.e. *Arctotipula illustris* Doane). In the Dundas Marsh the only specimen collected appeared in Cage 1 where most of the population of *Arctotipula illustris* emerged.

CULICIDAE

The collections of mosquitoes were reported upon previously by Judd (1950a).

Anopheles quadrimaculatus Say.—Two adults emerged in Cage 2 on September 3 (Table 1).

Anopheles occidentalis Dyar and Knab.—One mosquito emerged in Cage 3 on August 14 (Table 1).

Culex apicalis Adams.—Two mosquitoes were collected, one from Cage 1 on August 10 and one from Cage 4 on August 3 (Table 1).

Culex pipiens L.—Three mosquitoes emerged in the cages, one in Cage 1 on August 14 and two in Cage 3 on August 3 (Table 1).

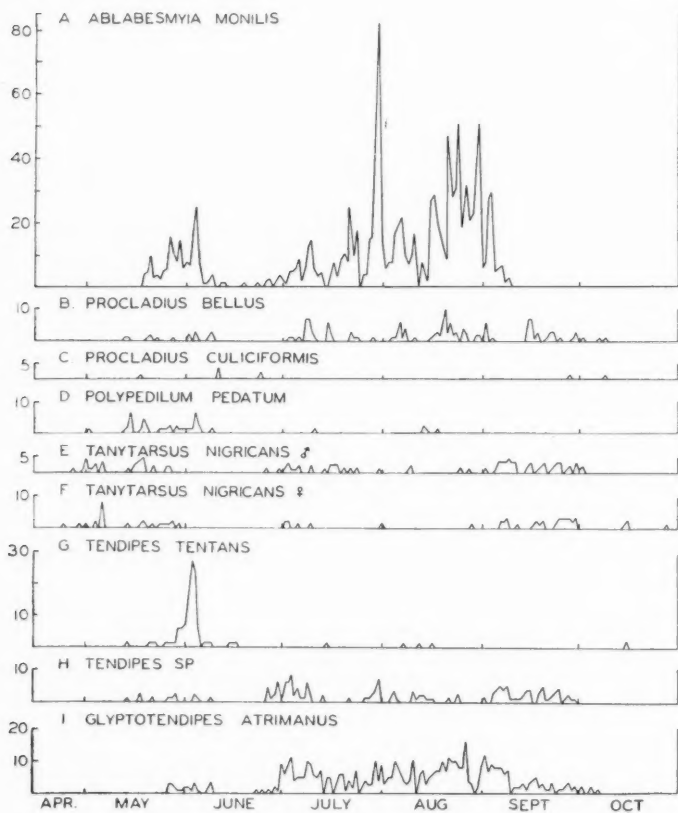


Fig. 5 (A-I).—Periods of emergence of adults of Diptera.

Mansonia perturbans Walker.—Two mosquitoes emerged, one in Cage 3 on August 2 and one in Cage 4 on August 14 (Table 1).

MYCETOPHILIDAE

Phronia rustica Winn. var. "a" Joh.—On fly emerged in Cage 1 on October 8 (Table 1).

TENDIPEDIDAE (Chironomidae)

Pelopia punctipennis Meigen.—Emergence period: May 18-September 29, maximum August 4 (326 insects; 2,160 day-degrees; Fig. 4E). This midge comprised more than one-quarter of the total emergents from all the cages, the great majority appearing in Cage 4 (Table 1). The species emerged in June and July in 1947 (Judd, 1949).

Ablabesmyia monilis L.—Emergence period: May 18-September 8, maximum July 30 (83 insects; 2,055 day-degrees; Fig. 5A). About half the insects emerged in Cage 3 (Table 1). In 1947 they appeared from June to September (Judd, 1949). Johannsen (1937), referring to this species as *Pentaneura monilis* L., reported that it is common in many localities in New York State, in ponds, pools and streams, often in masses of algae.

Procladius bellus Loew.—Emergence period: May 12-October 8, maximum August 19 (10 insects; 2,451 day-degrees; Fig. 5B). The majority of the midges emerged in Cages 4 and 5 (Table 1). In 1947 they emerged in May and June (Judd, 1949).

Procladius culiciformis L.—Emergence period: May 17-October 8, maximum June 10 (3 insects; 990 day-degrees; Fig. 5C). They appeared in all cages (Table 1). In 1947 these midges emerged in May and June (Judd, 1949). Johannsen (1937) says that "this cosmopolitan species is widely distributed throughout the United States.

Pseudochironomus middlekauffi Townes.—Five midges emerged in Cage 3, four on June 3 and one on June 4 (Table 1). Townes (1945) records collections of the species in New York State.

Polypedium pedatum Townes.—Emergence period: May 2-August 17, maximum May 14 (6 insects; 522 day-degrees; Fig. 5D). Most of these insects emerged in Cages 1 and 2 (Table 1). Townes (1945) reports this midge from several localities in New York State.

Tanytarsus nigricans (Johannsen).—Males: Emergence period: April 26-October 1, maximum May 18 (5 insects; 582 day-degrees; Fig. 5E).

Females: Emergence period: April 23-October 27, maximum May 5 (8 insects; 419 day-degrees; Fig. 5F).

Most of these insects emerged in cages 4 and 5 (Table 1). In 1947 they appeared in May and June (Judd, 1949). Johannsen and Thomsen (1937) record that larvae were collected in ponds near Ithaca, New York. Berg (1949, 1950a) found larvae inhabiting folds in rolled edges of floating leaves of four species of *Potamogeton*. It is probable that in the Dundas Marsh the larvae lived in the leaves of some of the seven species of *Potamogeton* present (Judd, 1950). *P. pectinatus* grew in Cages 4 and 5 where most of these insects emerged.

Tendipes tentans (Fabr.)—Emergence period: May 13-October 15, maximum June 2 (27 insects; 830 day-degrees; Fig. 5G). These insects emerged in Cages 3, 4 and 5 (Table 1). In 1947 some were caught in flight in June (Judd, 1949). Johannsen and Thomsen (1937) record that larvae were collected in a pond in New York State in May, July and December.

Tendipes sp.—Emergence period: May 13-September 29, maximum July 3 (9 insects; 1,462 day-degrees; Fig. 5H). Most of these midges emerged in Cages 4 and 5 (Table 1).

Glyptotendipes atrimanus (Coq.)—Emergence period: May 26-October 6, maximum August 26 (16 insects; 2,601 day-degrees; Fig. 5I). Most of these midges emerged in Cages 4 and 5 (Table 1). In 1947 they were trapped in June, August and October (Judd, 1949).

Glyptotendipes lobiferus (Say).—Emergence period: April 17-October 15, maximum July 12 (74 insects; 1,663 day-degrees; Fig. 6A). Most of these midges emerged in

Cages 4 and 5 (Table 1). In 1947 they were trapped from May to August (Judd, 1949). Berg (1949, 1950a) reports that the larvae burrow in stems of two species of *Potamogeton* and live in rolled leaves of another species.

Cricotopus trifasciatus Panzer.—Emergence period: April 14–October 27, maximum April 26, July 15, October 22 (59, 20, 12 insects; 307, 1,732, 3,489 day-degrees; Fig. 6B). Most of these midges emerged in Cages 3, 4 and 5 (Table 1). In 1947 the species emerged over a long period from May to October (Judd, 1949) with two peaks of emergence, one in July and one in October. Johannsen (1937) reports that it has a wide distribution in North America and that the larvae mine in the leaves of pond lily. Two species of lily grow in the Dundas Marsh (Judd, 1950) and one of them, *Nymphae*

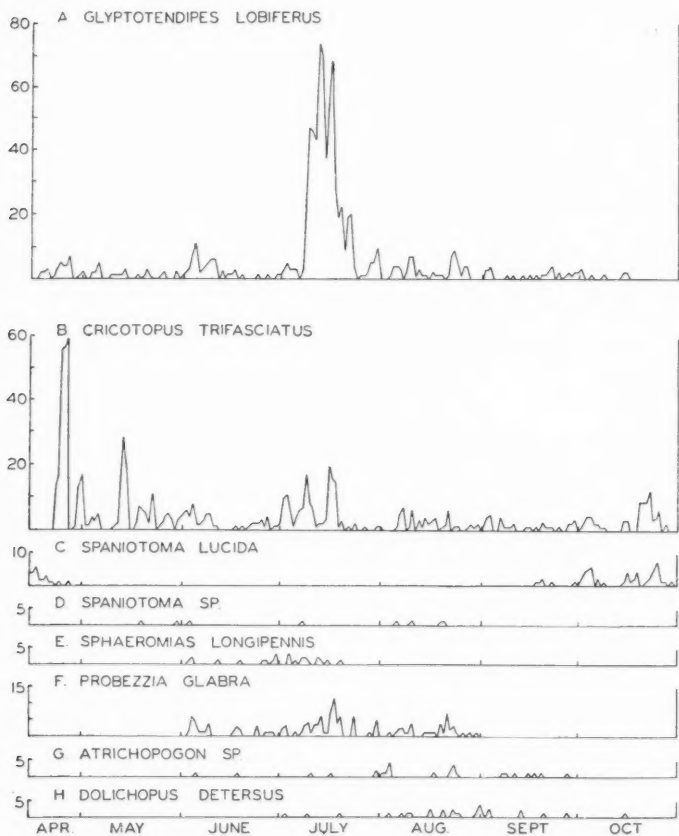


Fig. 6 (A-H).—Periods of emergence of adults of Diptera.

odorata, grew in Cage 4 where many of these midges emerged. Berg (1949, 1950a) records that the larvae form channels in the leaves of three species of *Potamogeton*, one of which, *P. nodosus*, grows in the Dundas Marsh (Judd, 1950).

Spaniotoma lucida Staeg.—Emergence period: April 14–October 29, maximum April 16, October 25 (6, 7 insects; 189, 3,509 day-degrees; Fig. 6C). Almost half the population of this species emerged in Cage 2 (Table 1), the insects showing two definite periods of emergence, one in early spring and the other in late fall. In 1947 collections were made from April to July (Judd, 1949).

Spaniotoma sp.—A few insects emerged in the cages during the season, the first appearing on May 18 and the last on August 20 (Fig. 6D). The majority emerged in Cage 2 (Table 1).

HELEIDAE (Ceratopogonidae) (Genera as in Johannsen (1943).

Sphaeromias longipennis L.—Emergence period: June 2–July 19, maximum June 29 (3 insects; 1,377 day-degrees; Fig. 6E). In 1947 the species was trapped in July and August (Judd, 1949). Johannsen and Thomsen (1937), referring to it as *Palpomyia longipennis*, record that it was collected in great numbers in blanket algae in a lake in New York.

Probezzia glabra Coq.—Emergence period: June 2–August 30, maximum July 17 (12 insects; 1,776 day-degrees; Fig. 6F). In 1947 this biting midge was trapped in July and August (Judd, 1949).

Atrichopogon sp.—Emergence period: June 4–September 27, maximum August 3 (4 insects; 2,139 day-degrees; Fig. 6G). Most of these midges emerged in Cages 3, 4 and 5 (Table 1).

STRATIOMYIDAE

Odontomyia vertebrata Say.—One fly emerged in Cage 2 on July 12. In 1947 four were trapped in Cage 1 and one in Cage 5 (Judd, 1949a). Curran (1927) gives records of collections of this species from several points in Ontario, and Hart (1896) reports rearing adults from aquatic pupae in Illinois.

DOLICHOPIDAE

Dolichopus detersus Lw.—Emergence period: July 2–October 15, maximum August 31 (3 insects; 2,715 day-degrees; Fig. 6H). Van Duzee (1921) records collections of this species in the vicinity of Toronto and Montreal.

Pelastoneurus vagans Lw.—Two flies emerged in the cages, one in Cage 2 on July 14 and one in Cage 1 on August 7 (Table 1). This species was collected in July in 1947 (Judd, 1949a).

Hydrophorus sp.—One fly emerged in Cage 2 on August 16 (Table 1). Curran (1934) writes that flies of this genus occur on the surface of small pools.

Sympycnus ? sp.—Emergence period: July 12–August 21; maximum August 18 (3 insects; 2,431 day-degrees). All but one emerged in Cage 1 (Table 1).

LONCHOPTERIDAE

Lonchoptera dubia Curran.—One fly emerged in Cage 2 on July 13 (Table 1).

SYRPHIDAE

Platycheirus quadratus Say.—One fly emerged in Cage 5 on July 21 (Table 1). Adults were collected from vegetation about the marsh in 1947 (Judd, 1949a). Osten Sacken (1878) reported collections of this fly in the Atlantic States and Fluke (1921) found it to be very common in swamps in Wisconsin.

Lejops stipatus (Wlk.).—One fly emerged in Cage 2 on June 15 (Table 1).

MUSCIDAE

Liipe albitarsus Stn.—Emergence period: May 19–September 19, maximum July 19 (8 insects; 1,820 day-degrees; Fig. 7A). This species appeared in all cages (Table 1). Several flies were trapped in cages in 1947 (Judd, 1949a).

Liipe uliginosa Flin.—Two adults emerged, one in Cage 2 on September 3 and one in Cage 3 on September 10 (Table 1). Puparia of this species were collected in muck of a pond at McLean, New York (Johannsen, 1935).

Hylemyia cana Macq.—One fly emerged on July 10 in Cage 4 (Table 1).

Spaziphora cincta (Lw.).—Emergence period: April 23–October 15, maximum May 17 (4 insects; 566 day-degrees, Fig. 7B). This species emerged in all cages except Cage 1 (Table 1). Osten Sacken (1878), referring to it as *Cordylura cincta*, records collections from the District of Columbia.

TETANOCERIDAE

Sepedon fuscipennis Lw.—Emergence period: June 30–September 8, maximum July 29 (3 insects; 2,034 day-degrees; Fig. 7C). These flies appeared in Cages 2, 3 and 5

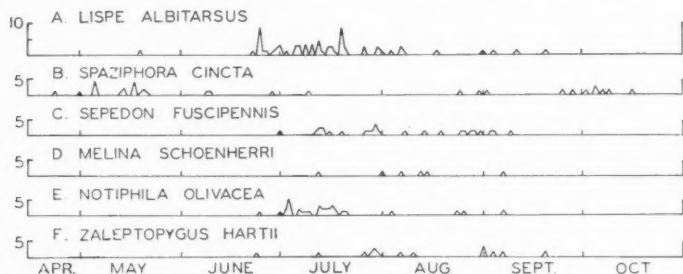


Fig. 7 (A-F).—Periods of emergence of adults of Diptera and Hymenoptera.

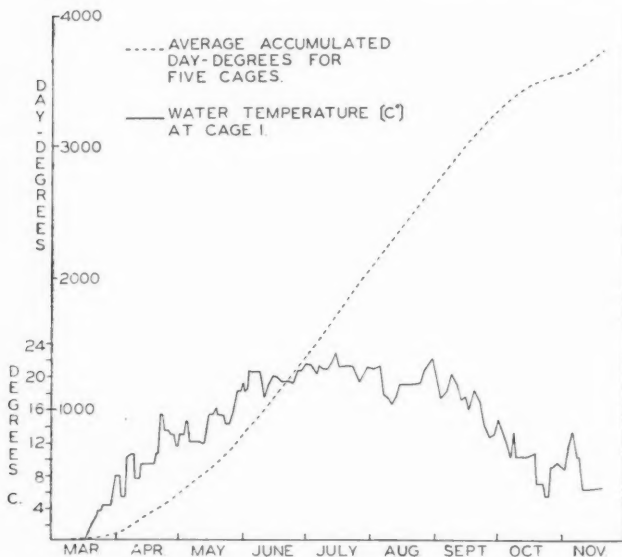


Fig. 8.—Water temperature at Cage 1; average accumulated day-degrees at cages.

(Table 1). Some were collected from vegetation about the marsh in 1947 (Judd, 1949a). Johannsen (1935) writes that pupae of this fly were found in August and October on the margin of a pond under overhanging vegetation near Ithaca, New York, and Osten Sacken (1878) reports collections from the Middle States.

Melina schoenherri Fln.—Emergence period: July 12–September 6 (Fig. 7D). Six flies emerged, four being trapped in Cage 5 (Table 1). Adults were swept from vegetation around the marsh in 1947 (Judd, 1949a).

EPHYDRIDAE

Scatella picea Wlk.—One fly emerged in Cage 3 on June 2 and one in Cage 4 on July 7 (Table 1).

Setacera atrovirens (Lw.).—Seven flies emerged in the cages between June 30 and October 1 (Table 1), the majority in Cage 2. In 1947 adults were swept from vegetation in August (Judd, 1949a). Johannsen (1935) states that a puparium from which an adult of *S. atrovirens* emerged was collected in a pool near Ithaca, New York.

Notiphila olivacea Cress.—Emergence period: June 24–September 6, maximum July 3 (5 insects; 1,462 day-degrees; Fig. 7E). This species emerged in all cages (Table 1). Williston (1908) reports that larvae of *Notiphila* have been observed in the stems of water plants, and Berg (1949) records larvae of *N. loewi* from the roots of three species of *Potamogeton*. It is likely that in the Dundas Marsh the larvae lived in the various plants of this genus (Judd, 1950).

Notiphila sp.—One adult emerged in Cage 4 on September 6 (Table 1).

Dichaeta caudata (Fln.).—Emergence period: June 30–July 15. Six adults emerged in the cages, appearing in all except Cage 5 (Table 1). Adults were swept from vegetation about the marsh in 1947 (Judd, 1949a). Osten Sacken (1878) records collections from Massachusetts.

Hydrellia griseola Fln.—Six flies emerged in the cages, two in Cage 1 on August 19, two in Cage 3 on May 14 and May 27, and one in Cage 4 on June 14 and one in Cage 5 on July 22 (Table 1). Williston (1908) reports that the larvae of *Hydrellia* have been observed in the parenchyma of *Lemna*, on *Alisma* etc., and Berg (1949) records collecting six species of *Hydrellia* from several species of *Potamogeton*. *Lemna minor* was on the surface of the water in all cages and one species of *Alisma* and several of *Potamogeton* grow in the marsh (Judd, 1950).

HYMENOPTERA

ICHNEUMONIDAE

Zaleptopygus hartii (Ashm.).—Emergence period: June 23–September 19 (Fig. 7F). This wasp appeared in all cages (Table 1). Hart (1896) took adults from the surface of Quiver Lake, Illinois, and his specimens were described as *Cremastus hartii* by Ashmead (1896). Cushman (1930) applied a "new combination" of names to the species, *Cremastus (Zaleptopygus) hartii* Ashmead. Berg (1950) found an adult of *Cremastus* sp. in a pupal case of the moth, *Nymphula icciusalis*. This species of moth and four other pyralid moths emerged in the cages, and it is likely that *Z. hartii* was parasitic on larvae of one or more of these moths in the marsh. Most of the wasps emerged shortly after peaks of emergence occurred in the populations of *Nymphula oblitalis* and *Acentropus niveus*.

Apilops hirtifrons (Ashm.).—One wasp emerged in Cage 4 on August 9. Hart (1896), referring to the species as *Cryptus cyaneiventris* Riley, reports that in Illinois it was common in July on floating leaves of *Potamogeton natans*, associated with *Hydrocampa* (i.e. *Nymphula*) *oblitalis* and was constantly present in August about the spot where the largest number of the *Hydrocampa* occurred. Cushman (1933) referred to this wasp as *Trichocryptus hirtifrons* (Ashmead) and said that Hart was the first actually to see the adult insects crawling under water. In the Dundas Marsh the wasp is probably a parasite on larvae of one of the pyralid moths. The commonest species of *Nymphula* in the marsh was *N. oblitalis* (Table 1) and it was with this species that the wasp was associated in Illinois.

CHALCIDAE

Chalcis canadensis (Cress.).—Three wasps emerged, one in Cage 2 on July 12, one in Cage 2 on July 13 and one in Cage 1 on August 5 (Table 1). Burks (1940) records

that the hosts of this species are *Odontomyia vertebrata* Say and *Odontomyia* sp. and Hart (1896) says that species of *Smicra* (*Chalcis*) have been reared from *Odontomyia* spp. It is very likely that *Chalcis canadensis* is parasitic on *Odontomyia vertebrata* in the Dundas Marsh. The specimen of *O. vertebrata* that emerged in 1948 appeared in Cage 2 on July 12 as did one specimen of *Chalcis canadensis*. Four of the adults of *Odontomyia* that emerged in 1947 (Judd, 1949a) appeared in Cage 1 between July 17 and August 5, a period that closely approximates the period of emergence of the adults of *C. canadensis* in 1948. All but one of the adults of *Odontomyia vertebrata* that

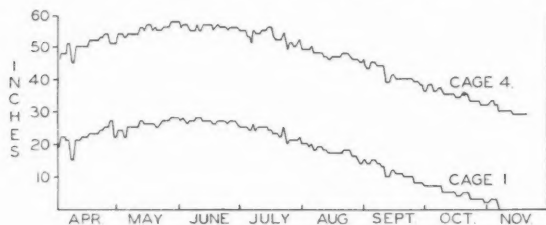


Fig. 9.—Depth of water at Cages 1 and 4.

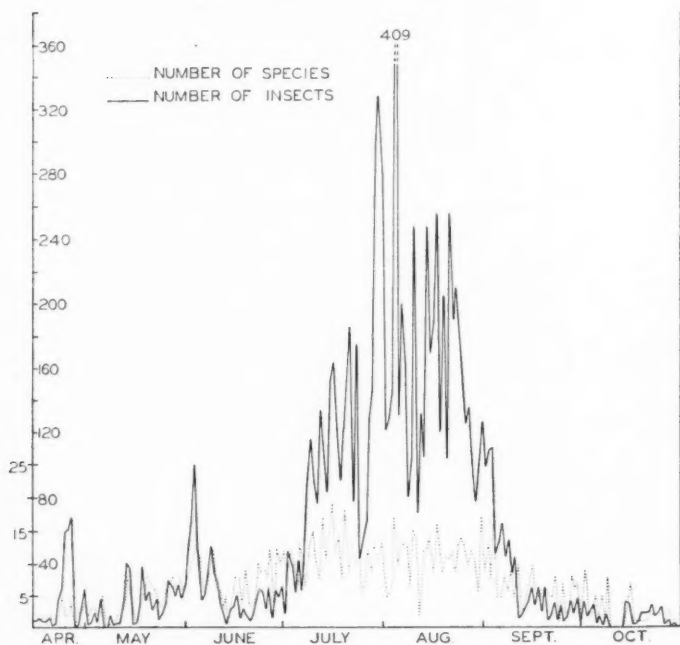


Fig. 10.—Numbers of insects and numbers of species that emerged during the season.

emerged in 1947 and 1948 appeared in Cages 1 and 2, indicating that the pupae of this fly inhabit shallow waters near the shore. All the adults of *Chalcis canadensis* emerged in these two cages.

SUMMARY

Between March 16 and November 20, 1948, 15,338 adult insects emerging from the waters of the Dundas Marsh were trapped in five cages, representing an average emergence of 409 insects per square foot during the period. The orders represented were Ephemeroptera (9.9 percent), Odonata (1.5 percent), Trichoptera (0.5 percent), Lepidoptera (0.9 percent), Diptera (87.1 percent), and Hymenoptera (0.1 percent). Midges of the family Tendipedidae (Chironomidae) constituted 92.5 percent of the Diptera. The times of first and last emergence and of maximum emergence of each species were recorded. The seasonal variation in the emergence of numbers of species was correlated directly with changes in temperature of the water, the day of emergence of maximum numbers of species being preceded by the day on which maximum temperatures were recorded at all cages.

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TABLE I.—Numbers of emergents from cages.

[illegible]

TABLE I.—(continued.)

| Species | Cage 1 | | Cage 2 | | Cage 3 | | Cage 4 | | Cage 5 | | Total No. of Insects |
|--------------------------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------------|
| | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | |
| Culicidae | | | | | | | | | | | |
| <i>Anopheles quadrimaculatus</i> | 0 | 0 | 2 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| <i>Anopheles occidentalis</i> | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 1 |
| <i>Culex apicalis</i> | 1 | 50.0 | 0 | 0 | 0 | 0 | 1 | 50.0 | 0 | 0 | 2 |
| <i>Culex pipiens</i> | 1 | 33.3 | 0 | 0 | 2 | 66.7 | 0 | 0 | 0 | 0 | 3 |
| <i>Mansonia perturbans</i> | 0 | 0 | 0 | 0 | 1 | 50.0 | 1 | 50.0 | 0 | 0 | 2 |
| Mycetophilidae | | | | | | | | | | | |
| <i>Phronia rustica</i> | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Tendipedidae | | | | | | | | | | | |
| <i>Pelopia punctipennis</i> | 1 | 0.02 | 6 | 0.15 | 60 | 1.51 | 3,841 | 93.21 | 210 | 5.11 | 4,118 |
| <i>Ablabesmyia monilis</i> | 96 | 7.8 | 127 | 10.0 | 688 | 53.8 | 151 | 11.7 | 214 | 16.7 | 1,276 |
| <i>Procladius bellus</i> | 1 | 0.7 | 2 | 1.4 | 16 | 10.7 | 78 | 52.3 | 52 | 34.9 | 149 |
| <i>Procladius culiciformis</i> | 2 | 25.0 | 1 | 12.5 | 1 | 12.5 | 3 | 37.5 | 1 | 12.5 | 8 |
| <i>Pseudochironomus middlekauffi</i> | 0 | 0 | 0 | 0 | 5 | 100 | 0 | 0 | 0 | 0 | 5 |
| <i>Polypedilum pedatum</i> | 32 | 72.7 | 10 | 22.7 | 1 | 2.3 | 0 | 0 | 1 | 2.3 | 44 |
| <i>Tanytarsus nigricans</i> | 2 | 1.1 | 12 | 6.5 | 32 | 17.3 | 68 | 36.7 | 71 | 38.4 | 185 |
| <i>Tendipes tentans</i> | 0 | 0 | 0 | 0 | 22 | 19.8 | 14 | 12.6 | 75 | 67.6 | 111 |
| <i>Tendipes</i> sp. | 1 | 0.6 | 0 | 0 | 10 | 6.3 | 77 | 47.9 | 73 | 45.2 | 161 |
| <i>Glyptotendipes lobiferus</i> | 9 | 1.0 | 46 | 5.3 | 109 | 12.7 | 199 | 23.1 | 500 | 57.9 | 863 |
| <i>Glyptotendipes atrimanus</i> | 0 | 0 | 1 | 0.2 | 34 | 6.7 | 270 | 53.6 | 199 | 39.5 | 504 |
| <i>Cricotopus trifasciatus</i> | 40 | 5.4 | 33 | 4.5 | 277 | 37.6 | 238 | 32.3 | 148 | 20.2 | 736 |
| <i>Spaniotoma lucida</i> | 3 | 3.4 | 40 | 46.5 | 22 | 25.6 | 4 | 4.7 | 17 | 19.8 | 86 |
| <i>Spaniotoma</i> sp. | 1 | 12.5 | 5 | 62.5 | 0 | 0 | 2 | 25.0 | 0 | 0 | 8 |
| Miscellaneous | | | | | | | | | | | |
| Tendipedidae | 546 | 13.3 | 132 | 3.2 | 604 | 14.7 | 1,650 | 40.1 | 1,176 | 28.7 | 4,108 |
| Heleidae | | | | | | | | | | | |
| Sphaeromias | | | | | | | | | | | |
| <i>longipennis</i> | 11 | 42.3 | 4 | 15.4 | 0 | 0 | 7 | 26.9 | 4 | 15.4 | 26 |
| <i>Probezzia glabra</i> | 17 | 12.6 | 52 | 38.5 | 22 | 16.3 | 29 | 21.5 | 15 | 11.1 | 135 |
| <i>Atrichopogon</i> sp. | 2 | 7.4 | 2 | 7.4 | 9 | 33.3 | 10 | 37.0 | 4 | 14.9 | 27 |
| Stratiomyidae | | | | | | | | | | | |
| <i>Odontomyia vertebrata</i> | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dolichopidae | | | | | | | | | | | |
| <i>Dolichopus detersus</i> | 10 | 37.0 | 3 | 11.1 | 6 | 22.2 | 0 | 0 | 8 | 29.7 | 27 |
| <i>Pelastoneurus vagans</i> | 1 | 50.0 | 1 | 50.0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| <i>Sympycnus</i> ? sp. | 7 | 87.5 | 1 | 12.5 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| <i>Hydrophorus</i> sp. | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE I.—(continued.)

| Species | Cage 1 | | Cage 2 | | Cage 3 | | Cage 4 | | Cage 5 | | Total No. of Insects |
|-------------------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------|------------------|----------------------|
| | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | No. of Insects | Percent of Total | |
| Lonchopteridae | | | | | | | | | | | |
| <i>Lonchoptera dubia</i> | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Syrphidae | | | | | | | | | | | |
| <i>Platycheirus quadratus</i> | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 100 | 1 |
| <i>Lepops stipatus</i> | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Muscidae | | | | | | | | | | | |
| <i>Lispe uliginosa</i> | 0 | 0 | 1 | 50.0 | 1 | 50.0 | 0 | 0 | 0 | 0 | 2 |
| <i>Lispe albitarsus</i> | 13 | 20.0 | 27 | 41.5 | 13 | 20.0 | 3 | 4.6 | 9 | 13.9 | 65 |
| <i>Hylemyia cana</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| <i>Spaziphora cincta</i> | 0 | 0 | 9 | 28.2 | 3 | 9.4 | 6 | 18.7 | 14 | 43.7 | 32 |
| Tetanoceridae | | | | | | | | | | | |
| <i>Sepedon fuscipennis</i> | 0 | 0 | 18 | 69.3 | 7 | 26.9 | 0 | 0 | 1 | 3.8 | 26 |
| <i>Melina schoenherri</i> | 0 | 0 | 1 | 16.7 | 0 | 0 | 1 | 16.7 | 4 | 66.6 | 6 |
| Ephydriidae | | | | | | | | | | | |
| <i>Scatella picea</i> | 0 | 0 | 0 | 0 | 1 | 50.0 | 1 | 50.0 | 0 | 0 | 2 |
| <i>Setacera atrovirens</i> | 1 | 14.3 | 5 | 71.4 | 0 | 0 | 1 | 14.4 | 0 | 0 | 7 |
| <i>Notiphila olivacea</i> | 5 | 14.7 | 16 | 47.1 | 6 | 17.6 | 2 | 5.9 | 5 | 14.7 | 34 |
| <i>Notiphila</i> sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| <i>Dichaeta caudata</i> | 1 | 16.7 | 3 | 50.0 | 1 | 16.7 | 1 | 16.6 | 0 | 0 | 6 |
| <i>Hydrellia griscola</i> | 2 | 33.3 | 0 | 0 | 2 | 33.3 | 1 | 16.7 | 1 | 16.7 | 6 |
| HYMENOPTERA | | | | | | | | | | | |
| Ichneumonidae | | | | | | | | | | | |
| <i>Zuleptopygus hartii</i> | 4 | 28.6 | 2 | 14.3 | 3 | 21.4 | 3 | 21.4 | 2 | 14.3 | 14 |
| <i>Apulops hirtifrons</i> | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| Chalcidae | | | | | | | | | | | |
| <i>Chalcis canadensis</i> | 1 | 33.3 | 2 | 66.7 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| TOTALS | 1,334 | 8.7 | 858 | 5.6 | 2,451 | 16.0 | 7,008 | 45.7 | 3,687 | 24.0 | 15,338 |

TABLE II.—Numbers of insects of the six orders that emerged in the cages.

| Order | Family | Cage 1 | | | Cage 2 | | | Cage 3 | | | Cage 4 | | | Cage 5 | | | ALL CAGES | | | |
|---------------|----------------|-------------------|---------------------|--|-------------------|---------------------|--|-------------------|---------------------|--|-------------------|---------------------|--|-------------------|---------------------|--|-------------------|-----------------------|-------------------|---------------------|
| | | No. of Insects | Percent of Total | | No. of Insects | Percent of Total | | No. of Insects | Percent of Total | | No. of Insects | Percent of Total | | No. of Insects | Percent of Total | | No. of Insects | Percent of Diptera | No. of Insects | Percent of Total |
| Ephemeroptera | | 36 | 2.4 | | 79 | 5.2 | | 341 | 22.5 | | 270 | 17.8 | | 791 | 52.1 | | 1,517 | | | 9.9 |
| Odonata | | 78 | 34.0 | | 57 | 24.8 | | 41 | 17.8 | | 27 | 11.7 | | 27 | 11.7 | | 230 | | | 1.5 |
| Trichoptera | | 0 | 0 | | 1 | 1.3 | | 18 | 24.0 | | 24 | 32.0 | | 32 | 42.7 | | 75 | | | 0.5 |
| Lepidoptera | | 27 | 20.1 | | 17 | 12.7 | | 50 | 37.3 | | 17 | 12.7 | | 23 | 17.2 | | 134 | | | 0.9 |
| Diptera | Tipulidae | 381 | 66.5 | | 136 | 23.7 | | 42 | 7.3 | | 5 | 0.9 | | 9 | 1.6 | | 573 | 4.3 | | |
| | Culicidae | 2 | 20.0 | | 2 | 20.0 | | 4 | 40.0 | | 2 | 20.0 | | 0 | 0 | | 10 | 0.1 | | |
| | Tendipedidae | 734 | 5.9 | | 415 | 3.4 | | 1,881 | 15.2 | | 6,595 | 53.4 | | 2,737 | 22.1 | | 12,362 | 92.5 | | |
| | Heleidae | 30 | 16.0 | | 58 | 30.8 | | 31 | 16.5 | | 46 | 24.5 | | 23 | 12.2 | | 188 | 1.4 | | |
| Hymenoptera | Other families | 41 | 17.7 | | 89 | 38.6 | | 40 | 17.3 | | 18 | 7.8 | | 43 | 18.6 | | 231 | 1.7 | | |
| | Total Diptera | 1,188 | 8.9 | | 700 | 5.2 | | 1,998 | 15.0 | | 6,666 | 49.9 | | 2,812 | 21.0 | | 13,364 | 100.0 | | |
| | | 5 | 27.8 | | 4 | 22.2 | | 3 | 16.7 | | 4 | 22.2 | | 2 | 11.1 | | 18 | | | 0.1 |
| TOTAL | | 1,334 | 8.7 | | 858 | 5.6 | | 2,451 | 16.0 | | 7,008 | 45.7 | | 3,687 | 24.0 | | 15,338 | | | 100.0 |

Studies in the Malachiidae — IV

M. Y. Marshall

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The continued identification of material in the Malachiidae, for various colleges and private collectors, has resulted in the discovery of a few additional species and also furnished new distributional records, as well as the information for synonymical and other notes on known species which are considered to be worthy of publication. It is the purpose of the present number of these studies to present this material.

COLLOPS ARIZONENSIS Marshall

This species was described (1951) from one male and three females, the female paratypes showing no variation of consequence when compared with the allotype. A series of 21 specimens, about equally divided between the sexes, collected by D. J. and J. N. Knull in the Chiricahua Mountains, Arizona, which is the type locality, shows that the species is remarkably constant for the genus and also that it is not rare if looked for in the proper place. It is quite a distinctive species and easily identified.

TANAOPS BASALIS Brown

Attalus blaisdelli Malkin. Pan-Pacif. Entom. 24(4):207 (new synonymy).

Included in the material from the California Academy of Sciences which was studied in connection with my *Studies in the Malachiidae III* (1951) was a female paratype of Malkin's species. This was not included in the key to *Attalus* which I gave in that paper because I could see no difference between it and female specimens of *T. basalis* in my collection. But, since I was unable to examine the male type of *blaisdelli* at the time, I refrained from mentioning my suspicion that it and *basalis* were the same species.

Through the kindness of Mr. Hugh B. Leech and Mr. J. W. Green, of the Academy, I have now been able to examine the male type of *blaisdelli* and have no hesitation in publishing the above synonymy. Malkin makes no mention of the male protarsi or any modification of the abdominal segments in his description of *blaisdelli*, but in this specimen they are typical of *Tanaops*. The second segment of the protarsus is slightly enlarged, but does not extend in a lobe over the third segment, as in *Attalus* and the fourth and fifth ventral segments show the typical ventral pits of *Tanaops*. Comparison with a male metatype of *basalis*, identified by Mr. Brown after comparison with his male holotype of that species, shows no difference in these structures and an unusually dark male of *basalis*, from Creston, B. C., matches the type of *blaisdelli* exactly as to such features as size, color, antennae and vestiture. The left antenna is missing from Malkin's type and the left foreleg is peculiarly

deformed, as though it had been broken off and an attempt made at regeneration. The specimen is labeled allotype, whereas Malkin states that the holotype is a male and the allotype a female. I think that the holotype and allotype labels must have been inadvertently placed on the wrong sexes.

Tanaops malkini, new species

Male: Oblong, the elytra gradually and moderately widened posteriorly, the apices separately rounded. Testaceous, the occiput, antennae (except the posterior face of the first three segments), palpi, a small spot at the upper end of the metasternal side pieces, and the legs distal to the mid-femoral regions black or piceous-black. *Head* moderately elongate, 1.3 times as long as wide, rather strongly depressed between the eyes, the labrum slightly infuscate; the surface shining, finely and sparsely punctate and pubescent. *Prothorax* quadrate, 1.2 times wider than long, the sides parallel, the angles rounded, the base and posterior angles slightly reflexed; surface very shining and practically glabrous. *Elytra* somewhat paler in color than prothorax, surface shining, minutely, fairly densely punctulate, the pubescence very fine, pale and inconspicuous, the erect and semierect, evenly distributed black setae more conspicuous. *Ventral surface* minutely and fairly densely punctulate and pubescent, more noticeably so on the legs. The protarsi have the second joint swollen and oblique, but not forming a free lobe over the third. The fourth and fifth sternites are each provided with a pair of pits at their posterior border, those on the fifth large and coalescent, those on the fourth much smaller and separated; the part of the fifth sternite not occupied by the pits depressed and glabrous. The lateral lobes of the sixth sternite end caudally in a long hook, that curves mediad and meets the one from the opposite side. The aedeagus protrudes posterior to this point and not through the opening between the lateral lobes, as would be expected.

Female: Similar to the male, except in the following respects. The head and metasternum are entirely black and the prothorax has an ill-defined, piceous discal spot that ends posteriorly in three lines, the median one the longest. The antennae are scarcely serrate and the abdominal segments are all unmodified. The front between the eyes is not so deeply impressed as in the male.

Length: Male 2.3 mm., female 2.5 mm.

Holotype, male and *allotype*, female collected "6 m. SW of Grand Coulee Dam, Grand Coulee, Washington, 19-24:VI:1950," by Mr. Borys Malkin, in whose honor the species is named. *Holotype* and *allotype* in the California Academy of Sciences. 23 *paratypes*, 15 males, 8 females, 12 with the same data as the types, 11 collected by Dr. M. H. Hatch, at Soap Lake, Washington, May 21, 1949. *Paratypes* in the collection of the California Academy of Sciences, in that of the Chicago Natural History Museum and in the collections of Mr. Malkin and of the author.

The paratypes show considerable color variation. As to the head, the extent of black on the occiput varies considerably; in two males and two females the front is blackish between the antennae; in four males and three females the head is entirely black, as in the allotype. In one male the prothorax has a large, oval, discal black spot; in one male the anterior margin only is black; four males show small, scattered, indefinite, piceous spots on

the prothorax. In one male and one female the thorax shows a pair of incomplete, parallel lines, with a central discal spot between them; in one female a black quadrangle with a pale center; in one female a pair of heavy black discal lines, while in one male and one female the prothorax is black with pale lateral margins. All but two of the specimens from Grand Coulee have the prothorax entirely pale, as in the holotype, while only two of the specimens from Soap Lake have the thorax similarly colored.

The species at first glance strongly resembles the pale color variety of *Attalus oregonensis* Leconte which the author (1951) described as *rubys*. A glance at the generic characters, protarsi and ventral pits, will separate the males; the females may possibly be distinguished by the longer head, more shining and less densely pubescent elytra, as well as the less reliable color characteristics of the black scutellum, head and legs. It is closely related to *Tanaops basalis* Brown, to which it runs in the author's (1946) key, except for the basal elytral spots. The head and thorax in *basalis* are, however, entirely black, except for narrow, red prothoracic basal angles and the ventral pits are of about the same size on both the fourth and fifth sternites, with both pairs coalescing. It is possible that more material may show this to be a pale color variety of *T. basalis*, which is much more variable than at first suspected, but the fact that in the darkest specimens, even though the yellow elytra become faintly marked with piceous, there is no trace of the black, triangular basal areas that characterize *basalis*, inclines me to consider it a distinct species.

ANTHOCOMUS BAKERI (Fall)

Malachius bakeri, Fall, Trans. Amer. Entom. Soc. 36:143.

Fall (1910) described this species from a single male specimen, collected at Claremont, California. Since that time, so far as I know, the species has not been mentioned in the literature, except for its listing in Leng's Catalogue, and the female still remains unknown. I have a female, which was collected with a typical male of the species. The exact locality, unfortunately, as well as the collector, is unknown, both specimens being labeled simply "So. Cal." The female is herewith described as the allotype.

Female: Similar to the male, except in the following respects. Form narrower, elytra parallel; an elongate piceo-testaceous spot on each humerus; the pale apical areas on the elytra more elongate anteriorly, terminating in acute angles about one-fifth the distance toward the elytral base; all the legs entirely piceous (in the male "hind tibiae pale in the apical two-thirds"). Antennae shorter, strongly serrate, the ninth segment widest, being as wide as long, the 5th to 8th inclusive almost as wide. Sculpturation and pubescence as in the male; elytral tips simple. Last sternite convex, depressed at the base; pygidium elongate, quadrangular, the tip broadly and squarely truncate. Length 4.0 mm.

Allotype, female, labeled simply "So. Cal.," in the collection of the author.

The elongate humeral spots, considered in connection with the equally elongate apical spots, suggest that in some pale specimens of this sex these spots may coalesce, forming a pale vitta on each elytron. Such specimens would strongly resemble females of *Malachius macer* Horn, together with the present species now placed in the genus *Anthocomus* (Marshall, 1949). The

female antennae of *macer*, however, are not so strongly serrate as in *bakeri*, the intermediate joints being distinctly longer than wide.

The presence of three males enables me to record some variation in that sex. In one, as in the holotype and the allotype, the prothorax is "pale reddish yellow with broad black median stripe," whereas in the other two the black median stripe is markedly dilated, leaving only the narrow lateral margins pale. In two males the pale apical spots are somewhat elongate, with the anterior ends angulate, while in one they are shorter and rounded anteriorly. In none are they so elongate or acutely angulate anteriorly as in the female. Fall does not mention the size or shape of the pale elytral tips, merely stating "elytra with pale tips."

ATTALUS PETTITI Horn

Six specimens of this species are before me, three from Ohio and three from Illinois. Two of these have the elytra colored as stated in Horn's description (1872), "elytra shining and with humeral and large apical black spot"; one has the apical black spot reduced to approximately the size of the humeral spot and in the remaining three the apical spot is entirely absent, thus corresponding almost exactly to Leconte's description of *humeralis* (1866), which was based on a single specimen from Illinois.

In a recent paper (1951) I mentioned the occurrence of specimens, identified as *humeralis*, from Brownsville, Texas, and expressed the opinion that the locality label on Leconte's type was probably an error. I now believe that Leconte described *humeralis* from a pale specimen of the species which Horn later described as *pettiti* and that the Brownsville specimens belong to an undescribed species. A comparison of the two species shows that the Illinois and Ohio specimens are all more elongate, more gradually widened posteriorly, with the elytra more shining and finely punctured. The Brownsville specimens are shorter, more oval and more strongly widened posteriorly, with the elytra dull, coarsely and closely punctate. A short look at Leconte's type would suffice to determine whether it is conspecific with *pettiti*.

ATTALUS SUBFASCIATUS Gorham

In 1951 I stated that I did not know on whose authority Leng had included this species in his 1920 Catalogue. I still do not know, but I have a male from Sabino Canyon, Arizona. This locality is in the foothills of the Santa Catalina Mountains, about ten miles north of Tucson, Arizona. This removes any doubt as to the occurrence of the species in our territory.

ATTALUS SUBTROPICUS Marshall

A series of 14 specimens of this recently described species (1951), collected by D. J. and J. N. Knull in Hidalgo, Cameron, and Goliad Cos. (Texas) shows more variation than was shown by the type series of only four specimens. The amount of black on the head varies from a narrow occipital band all the way to an entirely black head with a frontal pale triangular area. The width of the black thoracic stripe varies similarly, although it is more con-

stant. In one specimen the prothorax is black, with broad rufous posterior angles and in others the black stripe is more or less narrowed posteriorly. One male has the head and thorax uniformly rufotestaceous. The ground color of the abdomen is more rufous than in the types, where it is pale testaceous, and the first four segments are usually more or less heavily washed with piceous, with the posterior margins of the segments rufous. The females tend to have darker abdomens and legs than the males. In two males, the uniquely shaped ventral pits on the fifth sternite, by which the species is easily separated from its nearest ally, *rufiventris* Horn, are shallower and less well defined than in the male type and paratype. Lastly, the elytral vittae, which are only moderately narrowed antemedially in the types, are completely divided in two specimens and almost divided in a few others.

Attalus bicolor, new species

Male: Elongate, parallel. Color piceous black and yellow; head yellow, with the occiput black to the posterior third of the eyes, labrum and palpi piceous; antennae piceous, with the ventral surface of the first five segments yellow; prothorax yellow, with an oval discal spot, reaching the apex but not the base, piceous, the posterolateral portions of the spot paler; elytra dull sooty black, as in *otiosus*, faintly iridescent toward the base; legs and anterior two pairs of coxae yellow, the posterior pair of legs washed with piceous; under surface, posterior coxae and pygidium piceous black, shining. *Head* short, length-width ratio 0.85, surface shining, punctures and pubescence extremely minute and sparse. *Prothorax* slightly transverse, 1.3 times wider than long, the sides parallel, all the angles broadly rounded, the anterior margin slightly produced, the surface shining, punctuation and pubescence as on the head, with no erect setae. *Elytra* with sparse, very fine aciculate punctures and sparse, semierect brownish pubescence, with no admixture of erect setae that are distinguishable from the balance of the pubescence. *Ventral surface* with minute and sparse punctures and pubescence, the latter pale. Pygidium narrowly rounded at the apex and with a minute apical notch, as in *scincetus*. Lobes of second protarsal joints large, spatulate, with a pectinate black border along the inner margin and tip, consisting of about twelve minute teeth, which are well separated and perpendicular to the surface of the lobe. Ventral segments unmodified. Length 2.5 mm.

Female: Unknown.

Holotype, male, simply labeled "Texas," in the collection of the author. *Paratypes*, none.

The species runs to couplet 20 in my recent key to the genus *Attalus* (1951), which couplet contains the species *otiosus* (Say) and *scincetus confusus* Blatchley. From *confusus*, which very rarely has uniformly piceous elytra, it may be separated by the sooty character of the elytral surface and the uniform pubescence, which is dual in character in both *confusus* and *otiosus*, with fine prostrate pubescence and intermixed erect black setae. It is more closely allied to *otiosus*, but is smaller than average *otiosus* and definitely narrower. The pygidium in *otiosus* is quadrangular and broadly truncate at the tip, in both sexes. It further differs from *otiosus* by the nature of the

pubescence, in the same way as just described for *confusus*. The black margin of the protarsal lobes in *otiosus* shows a tendency to pectination, in a series of parallel, vertical striations and a finely dentate edge. The striations, however, which are analogous to the teeth in *bicolor*, are much more numerous than the latter. *Bicolor* will probably be found in many collections, mixed in with *otiosus*.

Attalus intermedius, new species

Male: Oblong, subparallel, the elytra slightly widened posteriorly. Black, the ventral surface of the first two antennal segments, a small spot just outside each antennal fovea, thorax (except a broad median prothoracic stripe), sutural and apical margins of elytra, coxae, trochanters, proximal ends of first two pairs of femora, meso- and metasterna (except the side-pieces), mesosternal epimera and first three abdominal segments rufotestaceous. *Head* long, length-width ratio 1.25, front shallowly and broadly impressed between the eyes, surface shining, punctation and pubescence extremely minute, a few erect black setae on the tempora. *Prothorax* slightly transverse, 1.2 times wider than long, the sides parallel, the angles rounded, the anterior margin slightly produced; surface shining, punctation and pubescence very fine, no erect setae present. *Elytra* finely rugulose and alutaceous, pubescence pale, decumbent, rather dense and very fine, the individual punctures not discernible; numerous, evenly distributed, erect, black setae, the punctures associated with these aciculate. The pale sutural margins occupy about the posterior half of the suture and are very narrow; the apical margins are wide and not well defined from the black discal areas. *Ventral surface* and legs densely and finely punctate and pubescent; fourth and fifth ventral segments each with a pair of well defined, narrowly separated pits, the posterior margin of the fifth segment sharply emarginate, the sixth composed of a pair of triangular lateral lobes, each terminated in a long, sharp, incurved spine or hook. Pygidium unusually large and almost semicircularly rounded. The protarsi have the first segment prolonged, oblique and applied to the inner edge of the second, which is even more prolonged, extending in a free lobe over the third segment. This lobe is straight on the inner edge, oblique on the outer edge, terminates in a sharp point, without any black margin, and reaches slightly beyond the middle of the third segment. Length 2.5 mm.

Female: Unknown.

Holotype, male, "Camp Baldy, Los Angeles Co., Calif. VII-II-50," in author's collection. *Paratypes*, none.

This species, as the name implies, is intermediate in several respects between the genera *Attalus* and *Tanaops*. It has the long head and ventral pits characteristic of *Tanaops*, but these features do occur in other species of *Attalus*. The character which I consider decisive for placing it in *Attalus* is the free lobe of the second protarsal joints, but this does not have the rounded tip, with the black margin, that characterizes most species of *Attalus*. It is more like the lobe in *A. rusticus* Fall, which also has ventral pits. If *intermedius* is considered to be a *Tanaops*, it runs to *T. oregonensis* Marshall in my key (1946) to that genus. *Oregonensis* is of the same size and color pattern, but the head is longer (length-width ratio, 1.7), the antennae are thicker and the

elytra are strongly shining and not at all alutaceous. In my key (1951) to *Attalus* it runs to *circumscriptus* except that the latter has the "elytra black, with all the margins (except the basal) narrowly and uniformly yellow." *Circumscriptus* also has no ventral pits and the elytra are shining, as in *T. oregonensis*.

NEW LOCALITIES

Collops tricolor (Say), Minnesota, Illinois, Arkansas, Nebraska, Ontario; *C. sublimatus* Schaeffer, Kentucky, Illinois, Maryland; *C. punctatus* Leconte, North Dakota; *C. hirtellus* Leconte, Montana; *C. lucens* Fall, North Dakota; *C. discretus* Fall, Arizona, British Columbia; *C. bipunctatus* (Say), Montana, North Dakota, Alberta; *C. limbellus* G. & H., Florida; *C. granellus* Fall, New Mexico, Mexico; *C. vittatus* (Say), New Mexico, Utah, Minnesota, Montana, North Dakota, Wyoming, Manitoba, Alberta; *C. quadrimaculatus* (Fab.), Iowa, Colorado, Minnesota; *C. versatilis* Fall, Nevada, Washington, Montana. *Anthocomus horni* (Fall), Montana; *A. mixtus* (Horn), Montana; *A. ulkei* (Horn), Minnesota; *A. montanus* (Leconte), California, Montana; *A. ventralis* Horn, Texas. *Attalus glabrellus* Fall, Oregon; *A. futilis* Fall, Colorado, California; *A. grisellus* Fall, Arkansas; *A. melanopterus* (Erichson), Arkansas; *A. circumscriptus* (Say), Illinois, Arkansas, New Mexico, Utah; *A. scincetus* (Say), Arkansas, Montana; *A. confusus* Blatchley, Iowa, Minnesota; *A. smithi* Hopping, Oregon; *A. greeni* Marshall, Missouri; *A. illinoisensis* Marshall, Arkansas.

The above records of new localities are in addition to those published in the third number of these "Studies" (1951).

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New Species in the Genera *Dipogon* Fox and *Minagenia* Banks (Hymenoptera: Psammodromidae) With Keys to Species and Photomicrographs of Genital Parts

R. R. Dreisbach
Midland, Michigan

Genus *Dipogon* FOX

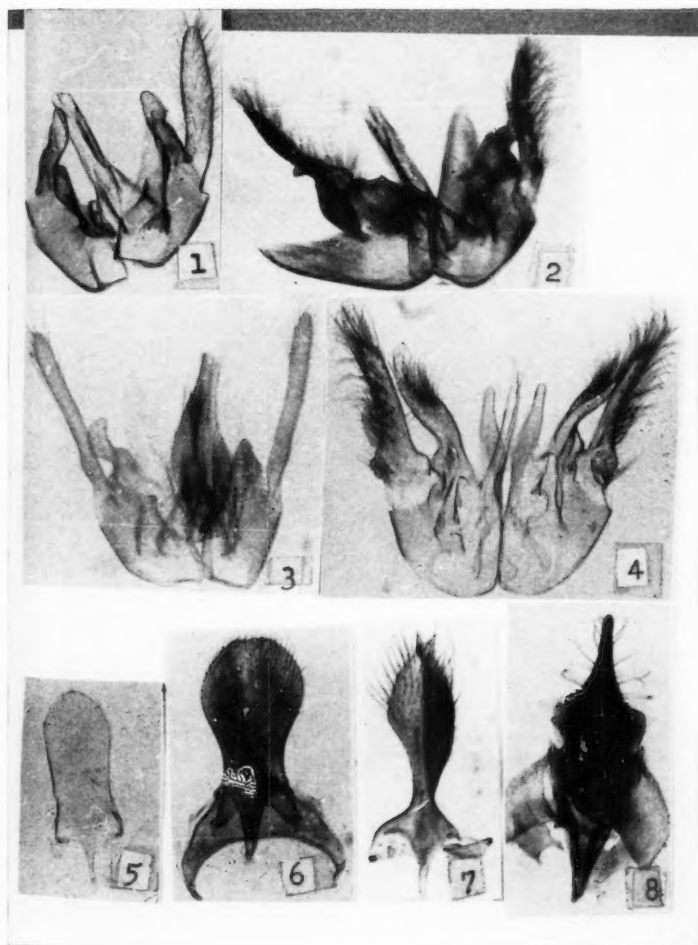
The Genus *Dipogon* seems to be intermediate between the *Cryptocheilinae* and the *Auplopodinae*. The basal abdominal segment is almost hour-glass shaped in some species and in others the sides are straight. In those that appear to be hour-glass shaped, however, the segment narrows rapidly, but then the sides are almost straight rather than expanding again at the base. The genus is most nearly related to *Priocnemis* in its genitalic characters. Because of the reasons mentioned it was placed in the *Cryptocheilinae* by the writer in his key (1951) to the genera of *Cryptocheilinae*.

The genitalic characters of *Adipogon* and *Dipogon* are very similar and, since the other differences seem to be very few (hardly enough to consider it a subgenus), the writer in the reference (1951) mentioned placed the species of *Adipogon* in the genus *Dipogon* Fox.

The two species described below are believed to be new.

Dipogon *femur-aureus* n. sp.

Holotype female.—Ground color black; antennae, mandibles maxillary and labial palpi, hair baskets, anterior edge of clypeus, posterior sides of pronotum, and the legs all yellow except the posterior tibiae are dusky; the sides of first abdominal tergite and the ventral surfaces of segments one and two are also tinged with yellowish; a number of long hairs on anterior dorsal surface of clypeus, on mandibles and ventral surface of pronotum, the head and thorax otherwise devoid of long erect hair except on dorsal surface of propodeum; a few long hairs on both dorsal and ventral surfaces of abdomen, the last segment of abdomen much more heavily covered with long upright hair of a light brownish color; head, thorax, and abdomen sparingly covered with appressed whitish hair but not having a sericeous appearance, except on the clypeus where they are the heaviest and give a slightly sericeous appearance in reflected light; mandibles four toothed, clypeus truncate; ocellar triangle low, vertex straight across when seen from in front, lateral ocelli equidistant from each other and the eye margin; third joint of antennae as long as the first two segments, and the rest of antennae missing; a dark band across basal and transverse veins in front wings, a second much broader covering about four fifths of the basal part of the marginal cell, second and third cubital cells, about one fourth of discoidal cell below them, and extending a short



Figs. 1-8.—1. *Minagenia shappirioi*, Gen. $\times 58$; 2. *M. clypeata* (Banks), Gen. $\times 60$ approx.; 3. *M. montisdorsa* n. sp., Gen. $\times 57$; 4. *Dipogon anomalus* n. sp., Gen. $\times 57$; 5. *Minagenia shappirioi*, Subg. $\times 60$; 6. *M. clypeata* (Banks), Subg. $\times 60$ approx; 7. *M. montisdorsa* n. sp., Subg. $\times 58$; 8. *Dipogon anomalus* n. sp., Subg. $\times 51$.

distance toward wing tip beyond discoidal; basal vein slightly before transverse vein, the veins in rear wings much disjoined.

Length: Head and thorax 3.65 mm, abdomen 3.0 mm, fore wing 5.3 mm, rear wing 3.65 mm.

Holotype female: Alto Pass, Ill., VIII-27-1889. No. 573 Hart. Sweeping. (Ill. Nat. Hist. Surv., Urbana).

Dipogon anomalus n. sp.

Figs. 4, 8

Holotype male.—Completely black, the whole insect with a shining appearance; a few long brownish hairs on lower side of clypeus and on mandibles; whole body covered with long white hairs, except abdominal tergites 2-4, and the first four abdominal ventral segments, all the coxae also with similar hairs; ocellar triangle bulging, when seen from in front, lateral ocelli nearer the eye margin than each other; clypeus covered with appressed white hair giving a sericeous appearance; front margin of clypeus slightly incurved in middle, when seen from side hardly bulging; head just in front of anterior ocellus level with the eye margins but the front bulging above this plane increasingly from there to base of antennae when seen from side; front and vertex strongly punctured; antennae much shorter than the other known males of the genus with a length of only 2.65 mm; third joint only about one and one third times as long as thick, about equal in length to the first and fourth; the antennae are also much more crenulate than in the other species; pronotum slightly angulate behind; pronotum, mesonotum, scutellum, propodeum, and sides of thorax punctured, the sides of propodeum much more strongly so than the dorsal surface, the sides of propodeum have a slight indication of transverse ridges; propodeum without a sulcus on dorsal surface; the legs beyond the tibiae with a slight tinge, longer spur of hind tibiae not quite half as long as the posterior basitarsal joint; last ventral segment, in dorsal view, with the apical half very narrow, and in the shape of a long narrow triangle, basal half much broader and abruptly truncated at about the middle, where it is reduced in width to about one third of its basal width; this segment with sparse long hairs on its edges; claws of legs split, with the outer ray long and sharp while the inner ray is very blunt and much shorter, the outer ray on the anterior legs bent slightly inward, while this ray on the other legs is more nearly straight; the basal vein slightly basad of the transverse vein, no cloud over the basal veins and only a very light cloud over the marginal and second and third cubital and part of the discoidal cells; venation just about like *D. sayi* Banks; genitalia (fig. 1) with a strong bunch of hair on the apical part of volsellae which with the much shorter antennae distinguishes it from *D. sayi*.

Length: Head and thorax 3.30 mm, abdomen 2.7 mm, fore wing 4.64 mm, rear wing 3.9 mm, genitalia width at base 0.6 mm, length 0.67 mm, subgenital plate length 0.93 mm, width 0.20 mm.

Holotype male: Cohasset, Mass., VIII-16-1924. A. Loveridge (MCZ).

Paratype: Orlando, Fla., March, 1944. G. E. Bohart (Bohart).

The paratype is slightly larger in size and the wings are much darker, fuliginous, but the genitalia and subgenital plates are identical.

KEY TO DIPOGON SPECIES

1. Median vein reaches to outer margin of wings 2
 Median vein does not extend to outer margin of wing 3
2. Thorax yellowish to rufous 3
 Thorax black 4
3. Head and abdomen black; antennae rufous, tips of joints narrowly black, legs partly black *texanus* Banks
 Head rufous, abdomen black; antennae rufous, joints not black; legs wholly yellowish *graenicheri* Banks
4. Face, mesonotum and abdomen with appressed grayish to yellowish pubescence; hair basket pale; front legs partly pale 5
 Without the pubescence as above 6
5. Erect black bristles on face and vertex; fore wings brown, tip snow-white; propodeum and pleura sericeous *sericeous* Banks
 No erect black hair as above; wing tip dark, not snow-white; propodeum and pleura without hair *brevis* (Cr.)
6. Tibiae and tarsi of fore legs partly pale, the four apical tarsal joints of last two pair of legs more or less yellowish; antennae yellowish underneath with the upper side blackish on basal half, yellowish on outer half; hair basket and maxillary palpi pale, as well as apical half of mandibles; a small species with narrowed first abdominal segment; third intercubital vein curved on inner side, not sloping forward in a straight line.
 Michigan and Eastward, Figs. 22, 24 *calipterus calipterus* (Say)
 California and Mexico. Antennal joints of male more crenulate than above *calipterus nubifer* (Cresson)
 Legs all black; hair basket yellowish, the parts recorded above as yellowish all black 7
7. Wings heavily banded with a strong basal band over basal vein and a broader one over marginal and cubital cells, especially in female, not quite so strong almost absent over basals in males, third intercubital vein almost straight and sloping inward strongly; parameres of male very long and heavy, volsellae narrow and shorter than aedeagus; subgenital plate somewhat ovoid with a narrow, wide ridge in center tapering off at each end. Figs. 19, 20 *sayi* Banks
 Female not known; wings hyaline to fuliginous, faint cloud in cells; third intercubital vein not sloping forward quite so strongly, and slightly bowed; parameres of genitalia only slightly longer than volsellae not heavy, and heavily haired with long hairs; volsellae wider than parameres, only slightly shorter, and with a heavy hair patch on apical third; subgenital plate broad at base, suddenly, abruptly narrowing about middle to a rather narrow apical half. Figs. 4, 8 *anomalous* n. sp
8. Fore wings wholly dark, almost black *papago* (Banks)
 Fore wings clear with dark bands over the basal veins, and the marginal and cubital cells; apex of wing milky white contrasting with dark bands 9
9. Legs all reddish yellow (except tibiae and tarsi are darker) as well as mandibles, apical edge of clypeus and the antennae *femur-aureus* n. sp.
 Legs all black as well as rest of body *pulchripennis* (Cr.)

DIPOGON FOX

Agenia Schiodte, Kröyer's Naturhist. Tidsskr. I, 1837, p. 321. Preoc. (Genotype-Sphex variegatus Linnaeus. Desig. Westwood 1840). *Pogonus* Dahlbom, Hym. Europaea, V, i, 1845, p. 453. Preoc. (Genotype-Sphex variegata Linnaeus. Desig. Pate, 1946). *Dipogon* Fox, Proc. Acad. Nat. Sci. Phila., 1897, p. 241. (o.d. Genotype-D. populator, Brazil). *Dipogon* Ashmead, Can. Ent., XXXII, 1900, p. 186. Key. *Deutrogenia* Susteria, Zool.-Bot. Gesell. Wien. Verh., 16, 1913, p. 191. N. name for *Agenia*. *Agriogenia* Banks, Can. Ent., LI, 1919, p. 83. (Genotype-Pompilus (*Agenia*) *brevis* Cresson). *Adipogon* Banks, Bull. Mus. Comp. Zool. XCIV, 1944, p. 181. (o.d. Genotype-Pompilus *pulchripennis* Cresson. Key. *Dipogon* Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 180. Key. *Dipogon* Bradley, Notule Naturae Acad. Nat. Sci. Phila., 145, 1944, p. 5 (desc.).

DIPOGON BREVIS (Cresson)

Pompilus (Agenia) brevis Cresson, Trans. Amer. Ent. Soc., I, 1867, p. 125, fig. 9. Male. (o.d., Ga., Amer. Ent. Soc.). *Agenia brevis* Cresson, Trans. Amer. Ent. Soc., 2, 1887, p. 272. Male. (Cat., Ga.). *Ageniella brevis* Banks, Jr. N. Y. Ent. Soc. XIX, 1910, p. 234. (key). *Agriogenia brevis* Banks, Can. Ent. LI, 1919, p. 83. (Genotype of new Gen.). *Agriogenia brevis* Leonard, Cornell Uni. Agr. Exp. Sta. Mem. 101, 1928, p. 988. (N. Y.). *Deutergenia brevis* Banks, Psyche, XL, 1933, p. 18. (key). *Dipogon brevis* Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 181. (key).

DIPOGON CALIPTERUS CALIPTERUS (Say)

Pompilus calipterus Say, Boston Jr. Nat. Hist., I, 1836, p. 302. o.d.). *Pompilus calipterus* Cresson, Proc. Amer. Ent. Soc., I, 1863, p. 316. (cat., Ind.). *Pompilus calipterus* Cresson, Trans. Amer. Ent. Soc., I, 1867, p. 93. (desc., Ind.). *Pompilus calipterus* Cresson, Trans. Amer. Ent. Co., 2, 1887, p. 270. (cat., Ind.). *Agenia caliptera* Fox, Ent. News, II, 1891, p. 196. (trans. to Agenia, Penna., N. J.). *Pseudagenia caliptera* Viereck, Rpt. N. J. State Mus. for 1909, 1910, p. 672. (N. J.). *Pseudagenia caliptera* Leonard, Cornell Uni. Agr. Exp. Sta. Mem. 101, 1928, p. 988. (N. J.). *Deutergenia pilosa* Banks, Psyche, XL, 1933, p. 16. Female (o. d. Ind. Mcz.). *Deutergenia caliptera* Banks, Psyche, XL, 1933, p. 18. (key). *Dipogon caliptera* Banks, Can. Ent. LXXIII, 1941, p. 122. (compares *D. sayi* Banks). *Dipogon pilosa* Banks, Can. Ent. LXXIII, 1941. (syn. of *D. caliptera*). *Dipogon caliptera* Banks, Bull. Mus. Comp. Zool., LCIV, 1944, p. 181. (key). *Dipogon (Deutergenia) calipterus calipterus* Townes, Hym. Amer. N. of Mex. USDA. Mono., No. 2, 1951, p. 912.

DIPOGON CALIPTERUS NUBIFER (Cresson)

Pompilus (Agenia) nubifer Cresson, Proc. Bost. Soc. Nat. Hist., 12, 1869, p. 374. Female. (o. d., Mexico). *Pseudagenia nubifer* Cameron, Biol. Centr. Amer. Hym., V, 1891, p. 167. *Pseudagenia nubifer* Bradley, Notulae Naturae, Acad. Nat. Sci. Phila., 145, 1944, p. 5. *Dipogon (Deutergenia) calipterus nubifer* Townes, Hym. Amer. N. of Mex. USDA. Mono., No. 2, 1951, p. 913. n. status.

DIPOGON GRAENICHERI Banks

Dipogon graenicheri Banks, Can. Ent., LXXI, 1939, p. 230. (o. d., Fla., MCZ). *Dipogon graenicheri* Banks, Bull. Mus. Comp. Zool., LCIV, 1944, p. 181 (key).

DIPOGON PAPAGO Banks

Deutergenia papago Banks, Psyche, XL, 1933, p. 17, Female (o. d. Ariz. Key, MCZ). *Adipogon papago* Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 181 (key).

DIPOGON SAYI Banks

Dipogon sayi Banks, Can. Ent., LXXIII, 1941, p. 122. (o. d., Va., N. C., N. Y., Penna., Conn., Mass., Canada, MCZ). *Dipogon sayi* Banks, Bull. Mus. Comp. Zool., LCIV, 1944, p. 181. (key).

DIPOGON SERICEUS Banks

Dipogon sericea Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 180. Female. (o. d., Ore., Oregon State College, key).

DIPOGON TEXANUS Banks

Dipogon texanus Banks, Bull. Mus. Comp. Zool., LCIV, 1944, p. 179. Female. (o. d., Texas, key, MCZ).

DIPOGON PULCHRIPENNIS (Cresson)

Pompilus (Agenia) pulchripennis Cresson, Trans. Amer. Ent. Soc., I, 1867, p. 123. Male, female. (o. d., Mass., Penna., W. Va., Amer. Ent. Soc.). *Pseudagenia pulchripennis* Rau, Wasp Studies Afield, 1918, pp. 84-85. (habits). *Agriogenia pulchripennis* Leonard, Cornell Uni. Agr. Exp. Sta. Mem. 101, 1928, p. 988. (N. Y.). *Pseudagenia pulchripennis* Brimley, Jr. Elisha. Mitch. Sci. Soc., 52, 1936, p. 115. Female. (pars.

desc., key, N. C.). *Pseudagenia pulchripennis* Brimley, Insects of N. C., 1938, p. 431. (N. C.). *Adipogon pulchripennis* Banks, Bull. Mus. Comp. Zool., LCIV, 1944, p. 181. (key).

Since this paper was written the "Hymenoptera of America N. of Mexico" USDA Mono. No. 2 has been published. In this monograph Townes splits the genus into two subgenera. The author has not had the opportunity to evaluate these subgenera and, hence, prefers to recognize these species as representing one genus.

Genus MINAGENIA Banks

In 1934 Banks (1944) erected the genus *Minagenia* to include two Philippine species. In 1944 he erected the genus *Nannochilus* for three American species, *Pseudagenia externa* Banks, *Pompilus congruus* Cresson, and a new species described at the time *Nannochilus osoria* Banks. Dr. H. K. Townes has called my attention to the fact that these two genera are synonymous and that *Minagenia* Banks, has priority.

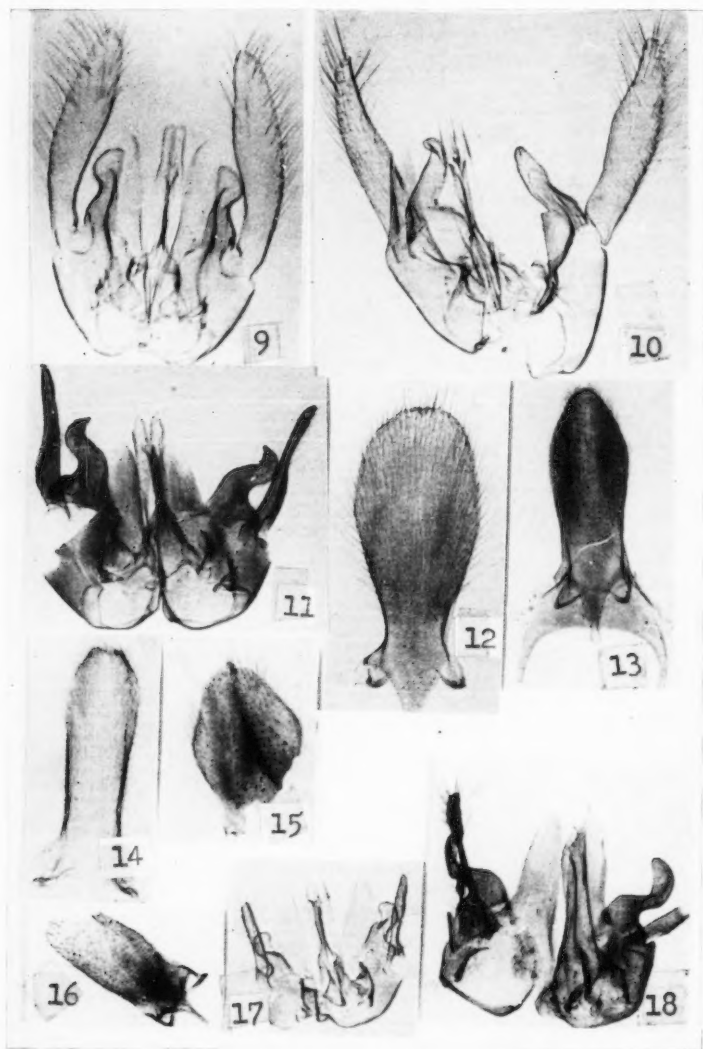
The species which the writer places in this genus are a very homogeneous group, much more so than in most genera. The venation is very characteristic, the third cubital cell is as long on the cubitus as on the marginal vein, the second and third intercubital veins are both bowed outward in the same amount at the middle, thus, each is convex on the inside and practically parallel over their whole length; the basal and transverse veins in forewings are interstitial or slightly disjointed and the subdiscoidal is either basad or of interstitial with the cubitus; the wings are hyaline or slightly brownish; fore legs are slightly yellowish, and generally the species are silvery sericeous; the claws are cleft in both sexes and the pulvelli of the claws are very large; the genitalia are very distinct and approach nearer to *Priocnemis* than any other genus; parameres are large and heavy or narrow, but in either case they are similar in appearance; the volsellae in every case have a deep curve about the outer middle unlike any other genus; aedeagus is split for about one-third of its length; the subgenital plates are very similar and are rather broad, hairy, but in one case it is very narrow with a wide ridge.

Some of the species described below may have been described in other genera, and under the female sex. However, I have not noticed any other species with the characteristic venation.

MINAGENIA OSORIA (Banks)

Figs. 11, 13

Male.—Black, tips of fore femora, fore tibiae and tarsi more or less, palpi and sides of first and second abdominal segments yellowish, spurs almost white; a few short hairs on vertex and mouth parts, and longer white hairs on sternites two, three, four, and five, those on latter two forming hair bands similar to the genus *Anoplus*; no hairs anywhere else; silvery sericeous on clypeus, face, inner orbits, outer orbits, coxae, slightly so on rest of legs, the whole thorax, and less so on abdomen; when seen from the side, the eyes just reach the clypeus and almost to top of vertex, posterior orbits hardly visible, clypeus flat, front only visible at antennal fossae; when seen from the front, the vertex



Figs. 9-18.—9. *Minagenia michiganensis* n. sp., Gen. $\times 60$ approx.; 10. *M. semirufa* n. sp., Gen. $\times 59$; 11. *M. osoria* (Banks), Gen. $\times 48$; 12. *M. michiganensis* n. sp., Subg. $\times 60$ approx.; 13. *M. osoria* (Banks), Subg. $\times 48$; 14. *M. semirufa* n. sp., Subg. $\times 53$; 15. *M. teapae* (Cameron), Subg. $\times 60$ approx.; 16. *M. minor* n. sp., Subg. $\times 54$; 17. *M. minor* n. sp., Gen. $\times 58$; 18. *M. teapae* (Cameron), Gen. $\times 60$ approx.

rises slightly above eyes in a smooth curve, inner orbits parallel, just barely diverging to vertex, middle interocular distance one-half transfacial distance, head broader than long, width one and one-half length, a very short low ridge in middle above antennal fossae, front and head reticulated; antennae long and slender, longer than head and thorax; comparative lengths of first four and last two joints are 3.5:1:3:3:3:3, the third about twice as long as thick; anterior ocellus its diameter from laterals and these as far apart as their distance to eyes; pronotum very slightly angulate behind, almost vertical in front, propodeum in a smooth low curve, a semicircular area separated at base with a groove in center and bounded by a semicircular groove; when seen from above, there is a slight ridge running forward on sides of propodeum from the outer posterior corners; wings hyaline, slightly yellowish and just barely darker on tips; marginal cell longer than its distance to wing tip, the third cubital cell parallel-sided as is peculiar to the genus; basal veins in fore wings interstitial, the subdiscoidal in rear wings basad of cubitus; legs very long, with the posterior coxae with a groove on upper surface, the ridges very evident, the middle coxae similar, fore coxae not grooved; the vertical surface of last two pair of coxae expanded outward in the middle, thus forming a hump; all femora and tibiae, except last tibiae, free of spines, the posterior tarsi with a few very small, hardly visible spines; tarsi well spined with small spines; claws all cleft, and with very large aroliae; comparative length of joints of posterior legs starting with femur, 40:40:30:12:10:5:4 (without claw); longer joint of posterior tarsi two-thirds its metatarsal joint; parameres slender, fairly short, and tapering gradually to tip with no long hairs; volsellae longer than parapenal lobes, slightly shorter than aedeagus; subgenital plate oblong, broadest about upper third, slightly arched in center.

Length: Head and thorax 3.90 mm, abdomen 4.0 mm approx., fore wing 6.30 mm, rear wing 4.3 mm, genitalia length 0.73 mm, width 0.58 mm, subgenital plate length 0.66 mm, width 0.20 mm.

Minagenia shappirioi n. sp.

Figs. 1, 5

Holotype male.—Black with fore legs light yellow, fore coxae partly so, spurs white; small spots of reddish-yellow on undersides of first two antennal joints; face, clypeus, inner orbits, coxae beneath, thorax (pleura strongest) and abdomen, silvery sericeous; a few upright hairs on vertex and more on neck, with a very few on ventrites, none elsewhere. When seen from the side, eyes extend from just beyond base of clypeus to just barely below vertex, ocelli visible, hardly any of front visible, clypeus with a very slight bulge, posterior orbits hardly visible; when seen from above, eyes barely diverging above, practically parallel, ocellar triangle just above vertex, transfacial distance slightly greater than the middle interocular distance, head about as wide as long, sharp ridge extending from front and middle of antennal fossae almost half way to fore ocellus, no line or groove on front; ratio of lengths of first three antennal joints (rest lost) are 3:1.2:3, third joint not quite three times as long as wide; pronotum vertical in front, not angulate behind, almost transverse; propodeum and wings similar

to preceding species; abdomen slightly sericeous and with only a very few hairs on sternites; legs similar to preceding, most of joints lost; genitalia very much like those of *M. semirufa* n. sp., except smaller and parameres are shorter and slightly different shape; subgenital plate short and broad, broadest at about apical fourth.

Length: Head and thorax 3.7 mm, abdomen 4.0 mm, fore wing 6.3 mm, rear wing 4.0 mm, genitalia length 0.66 mm, width 0.40 mm, subgenital plate length 0.53 mm, width 0.26 mm.

Holotype male: Oscola Co., Mich., VIII-3-1940, R. R. Dreisbach (MCZ).

***Minagenia montisdorsa* n. sp.**

Figs. 3, 7

Holotype male.—Black, with only traces of yellow on fore tibiae, spurs pale; clypeus, face, thorax, coxae, and abdomen (slightly) sericeous; a very few short hairs on vertex, mouth parts and neck only; when seen from the side, the eyes extend just beyond the base of clypeus, and just about reach top of vertex, but the ocelli are visible, as well as antennal fossae and the front slightly back of fossae, clypeus flat, posterior orbits not visible; when seen from the front, the ocellar triangle stands out as a slight mound, sides of ocelli on plane with eyes, head just about as long as wide, middle interfacial distance just about one-half the transfacial distance; indication of a slight ridge on middle of fore part of front; posterior ocelli about as far apart as their distance to eye margin; ratio of lengths of first four and last two antennal joints is 3:1:3:3:1.5:3; pronotum vertical in front, transverse behind, propodeum and wings similar to preceding; abdomen slightly sericeous and shiny, no upright hairs; legs as in preceding; ratio of lengths of joints of posterior legs starting with femur 35:35:28:11:9:4:4; longer spur of posterior tibiae is about two-thirds its metatarsal joint; genitalia with the parameres long and slender, with long hairs near the tip, parapenial lobes as long as aedeagus; subgenital plate characteristic, rather narrow, roof-shaped, tapering off from about the center to tip.

Length: Head and thorax 3.65 mm, abdomen 3.6 mm approx., fore wing 6.0 mm, rear wing 5.3 mm, genitalia length 0.78 mm, width 0.53 mm, subgenital plate length, 0.66 mm, width ? mm.

Holotype male: Ross Co., Ohio, 2-9-40, D. J. Borror (Ohio State Univ.).

Paratype male: Louisiana, 2547, C. F. Baker (U.S.N.M.).

The measurements of the paratype are close to the type. The width of subgenital plate is not available, since in the slide it is mounted sideways.

***Minagenia minor* n. sp.**

Figs. 16, 17

Holotype male.—Black, first two joints of antennae red, mandibles in middle, fore legs and middle tibiae more or less yellowish; clypeus and face silvery sericeous, and thorax much less so, the abdomen slightly silvery and more or less cinereous in certain light; when seen from the side, no part of vertex or ocelli visible, only antennal fossae, clypeus flat, posterior orbits and clypeus just slightly bulging; front granular; when seen from in front, ocellar

triangle just visible, middle interocular distance slightly less than transfacial distance, head only eight-tenths as long as wide, a smooth line on anterior half of front; lateral ocelli as far apart as their distance to eyes; ratio of lengths of first 4 antennal joints are 2:1:2:2.2:2; pronotum almost vertical in front, slightly angulate behind; propodeum and wings about like the other species; abdomen small, slightly flattened sideways at tip; legs similar to others; ratio of length of joints of posterior legs starting with femur is 25:25:15:6:4:3, last joint lost; longer spur of posterior tarsi two-thirds length of its metatarsal joint; parameres narrow, hardly longer than aedeagus, parapenial lobes as long as aedeagus and volsellae only slightly shorter; subgenital plate narrow, rather long for width, broadest slightly basad of middle and tapering slightly to an obtuse point.

Length: Head and thorax 2.3 mm, abdomen 2.3 mm, fore wing 4.0 mm, rear wing 3.3 mm, genitalia length 0.38 mm, width 0.40 mm, subgenital plate length 0.53 mm, width 0.12 mm.

Holotype male: Hamburg Farm, Costa Rica, April 20, C. W. Dodge (MCZ).

Paratype male: Same data (RRD).

The paratype is pretty well broken up, but is of about the same size as type. Much the smallest species of the genus about 4.6 mm overall in length, the rest are all over 7.2 mm in length, the genital parts are also the smallest.

Minagenia semirufa n. sp.

Figs. 10, 14

Holotype male.—Black, except all of the first two abdominal segments, the ventral part and two-thirds of the dorsal part of the third abdominal segment are red; and the fore tibiae and tarsi are slightly yellowish; the apical dorsal third of abdominal tergite is black; slightly sericeous but not nearly so much so as any of the preceding, and on the sericeous covering somewhat coarser; a very few upright hairs on vertex mouth parts, more under head on the neck, and very short (hardly noticeable) more numbeous ones on pronotum, the propodeum with a very short, scant, mat of very short ones on sides (no really upright ones) reminiscent of some species of *Evagetes*; a few hairs on apical tergites, the third, fourth and fifth sternites with small, short-haired mats reminiscent of *Anoplius virginensis* (Cr.); when seen from the side, the clypeus is flat, no part of vertex but the nearer lateral ocellus is just visible and the front at antennal fossae, posterior orbits plainly visible, about one-third width of eyes; when seen from in front, eyes parallel just barely diverging at apex, middle interocular distance just barely less than one-half transfacial distance, head almost 1.3 times as wide as long; lateral ocelli one and one-third times as far from eyes as they are apart; a smooth raised line on middle front just above antennal fossae; ratio of length of first four and last two antennal joints are 30:10:3.5:40:32:40, third three and one-half times as long as wide; fore part of pronotum vertical, and posterior border is not angulate; propodeum similar to others, and has the outer posterior corners strongly sericeous in reflected light, but it also has a plainly evident line on basal one-half in the middle; wings similar to others in genus except the basal

vein in fore wings is slightly basad of the transverse; legs similar to the other species; comparative lengths of joints of posterior leg are 40:42:20:13:9:5:5; longer spur of posterior tarsi two-thirds the length of its basitarsal joint; parameres large, long, heavy tapering in upper third and the latter section with some long hairs, aedeagus slightly longer than volsellae and parapenial lobes; subgenital plate very narrow and small, parallel-sided on basal half, slightly expanded above.

Length: Head and thorax 4.0 mm, abdomen 3.5 mm, fore wing 6.6 mm, rear wing 5.1 mm, genitalia length 0.86 mm, width 0.53 mm, subgenital plate length 0.66 (without stem) mm, width 0.20 mm.

Holotype male: Petersham, Mass., 7-40, C. T. Brues (MCZ).

Minagenia michiganensis n. sp.

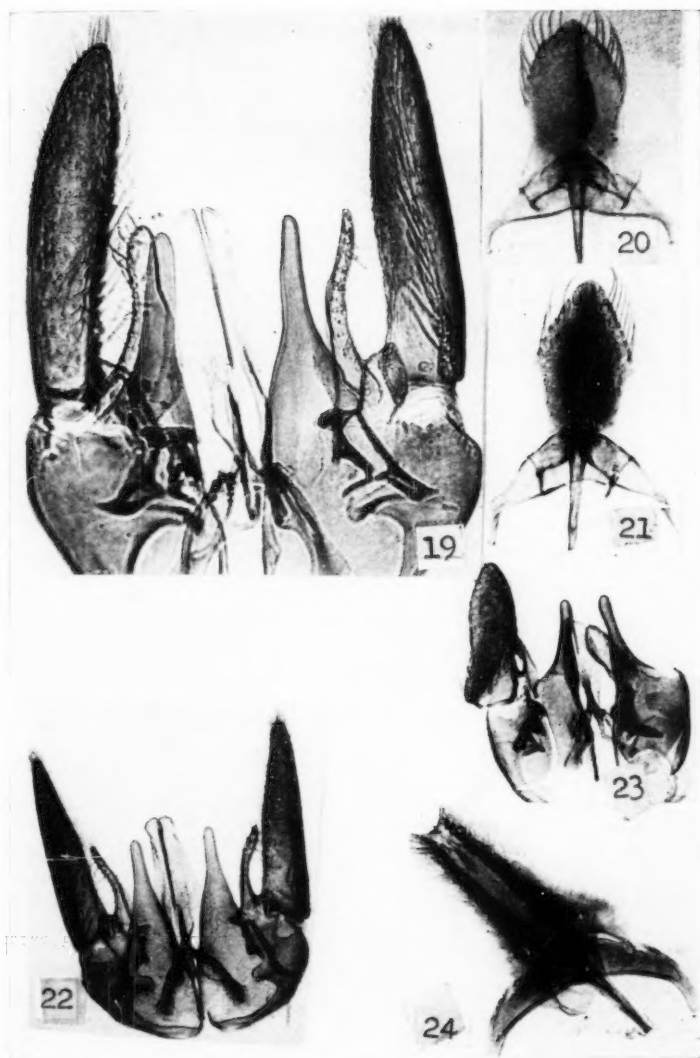
Figs. 9, 12

Holotype male.—Black, with the first three abdominal segments completely red; white, glistening, appressed hair over most of thorax and coxae with slight traces on rest of legs; hardly any upright hairs on body anywhere; head small, slightly lenticular when seen from side, with eyes broad but short; when seen from side, the vertex and nearer posterior ocellus visible above eye, front only slightly raised above eye at antennal fossae, eyes twice as wide as posterior orbits, clypeus almost flat; when seen from in front the vertex is arched above eyes, the head is almost square, and the clypeus is truncate in front, inner orbits parallel, distance between the eyes eight-thirteenths the transfacial distance, mentum light colored and visible beyond clypeus; mandibles reddish at tip; posterior orbits slightly closer together than their distance to eye margin, located at the very top of the eyes; antennae rather long and tapering, ratio of length of first four and last two joints, 30:10:30:35:30:35; labial palpi long, slender, and light colored; pronotum slightly angulate behind, propodeum rather flat with hardly any slope at posterior end; wings slightly yellowish, even slightly fumous, with the tegula, base of wings and costa to stigma, light colored, more so than other veins; both recurrent veins received about middle of their cells, second cubital almost square and third slightly longer, first recurrent vein bowed slightly inward, the second and third bowed outward as is usual in the genus; basal vein basad of transverse in fore wings and the veins in rear wings almost interstitial; abdomen colored as noted above with a slight bloom; apex of fore femora and tibiae slightly yellowish, the apex of tibiae and tarsi of last two pair slightly light colored; all spurs white, claws all split, longer spur of posterior tibiae slightly more than two-thirds as long as its metatarsal joint; all legs practically devoid of spines; parameres thick, thickest in the middle, subgenital plate somewhat abovate, much the widest in apical half.

Length: Head and thorax, 4.6 mm, abdomen 4.0 mm approx., fore wing 6.6 mm, rear wing 5.6 mm, genitalia length 0.80 mm, width 0.60 mm, subgenital plate length 0.80 mm, width 0.33 mm.

Holotype male: Roscommon Co. Mich., VII-14-45, R. R. Dreisbach (MCZ).

Agonia rufigaster (Prov.) was described in female only and the writer does not know this species and is not sure that it belongs here as listed by Townes (1951).



Figs. 19-24.—19. *Diogon sayi* Bks., Gen. $\times 125$; 20. *D. sayi* Bks., Subg. $\times 65$; 21. *D. brevis* (Cr.), Subg. $\times ?$; 22. *D. caliptera* (Banks), Gen. $\times 41$; 23. *D. brevis* (Cr.), Gen. $\times ?$; 24. *D. caliptera* (Banks), Subg. $\times 40$.

KEY TO MINAGENIA SPECIES

(Males and Females)

1. Females 2
Males 3
2. Abdomen completely red; legs and spurs black except fore tibiae yellowish
 *congrua* (Cresson)
 Abdomen not red; legs yellowish red, four hind tibiae and tarsi are black on outer side; a distinct rufous spot on each side of first and second abdominal segments; pronotum subangulate behind *externa* (Banks)
3. Abdomen partly red 4
Abdomen black 6
4. Only the first two abdominal segments red; greater part of the legs reddish-yellow, hind tibiae and last two pair of tarsi dark brown; a black stripe on outer side of last two pair coxae; all tibial spurs white; longest spur of posterior tibiae over three-fourths length of its metatarsal joint; tibial spurs white *julia* (Brimley)
 More than first two abdominal segments red; only fore tibiae and tarsi yellowish if colored at all 5
5. First three abdominal segments completely red and the telescoped bases of fourth and fifth reddish; glistening silvery sericeous hairs on thorax and coxae, but not so much as in species after couplet 6; fore tibiae and tarsi yellowish, palpi and spurs light; parameres heavy not reduced much at tip; subgenital plate somewhat ovate, much wider in apical half. Figs. 9, 12 *michiganensis* n. sp.
 First two abdominal segments only completely red; the third red on telescoped part but with a broad black or apical border; not much silvery pubescence; palpi dark, spurs light, parameres not so heavy and more pointed; subgenital plate almost rectangular, the sides parallel except about apical third where the plate expands slightly. Figs. 10, 14 *semirufa* n. sp.
6. Clypeus with the apical edge pale, palpi pale; first two pair of coxae beneath, fore legs and middle tibiae yellowish-white; underside of first two antennal segments, posterior coxae and femora beneath, and underside of abdomen with slight reddish or yellowish color; spurs white; parameres very narrow, subgenital plate rather short and broad. Figs. 2, 6 *clypeata* (Banks)
- Clypeus black and if some color on legs not nearly as much as above 7
7. Silvery sericeous on face, coxae and thorax; a slight but very noticeable ridge in middle of front just above antennal fossae, very short and does not extend half way to fore ocellus; fore legs yellowish, spurs white; parameres heavy. Figs. 1, 5 *shappirioi* n. sp.
 Almost as silvery as above in some species but without the frontal ridge above (an indication in some cases) and not as much color 8
8. Silvery pubescent with long white hairs on sternites, those on sternites five and six almost as strong as the hair bands on some species of *Anoplius*; eyes reach to top of vertex; fore tibiae and tarsi slightly yellowish, spurs and palpi pale; parameres very slender, parapenial lobes much shorter than aedeagus; subgenital plate sloped, not quite flat, fairly broad. Figs. 11, 13 *osoria* (Banks)
 No white hair bands or mats on sternites five and six, the rest of hair not white 9
9. Basal two joints of antennae red, rest black; first two pair of tibiae and tarsi yellowish, posterior legs almost black; spurs white; a very small species. Costa Rica. Figs. 16, 17 *minor* n. sp.
 Basal two joints of antennae not red 10
10. Parameres long and slender, parapenial lobes as long as aedeagus; subgenital plate with a wide ridge in center, reaching its greatest width near center and tapering off to the tip, shown sideways in plate; ridge very similar to *Dipogon sayi* Banks; eyes diverging above. Eastern N. A. *montidorsae* n. sp.
 Parameres short, expanding near tip, and with numerous, long hairs from this expanded tip; subgenital plate broad, short and with a triangular elevation of basal half; eyes converging above. Mexico. Figs. 15, 18 *teapae* (Cameron)

MINAGENIA Banks

Minagenia Banks, 1934. Proc. Amer. Acad. Arts and Sci., LXIX, pp. 40, 64 (Jan. 1934). (Type: *Pseudagenia* (*Minagenia*) *brevicornis* Banks, 1934.). *Nannochilus* Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 171. (and *N. osoria* Banks).

MINAGENIA CLYPEATA (Banks)

Ageniella clypeata Banks, Jr. N. Y. Ent. Soc., XXII, 1914, p. 306. Males. (o. d., Va., M.C.Z.). *Ageniella clypeata* Banks, Bull. Mus. Comp. Zool., XCIV, 1944, p. 178. Male (Eastern, key).

MINAGENIA CONGRUA (Cresson)

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The Orb-Weaving Spiders of the Chicago Area

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The spiders of the southern shores of Lake Michigan and vicinity have not been treated as a unit although Banks (1905), Elliott (1932) and others have included parts of this area in lists of spiders of surrounding states. From 1932 to 1942, the author collected in the Chicago area (roughly including the drainages of the Illinois and Fox rivers) on more than 125 field trips, each of which averaged about one day in extent. As a result, over 300 species have been identified within about 50 miles of Chicago. Future papers will present the results of this collecting. The forty-one species of cribellate orb-weavers found in the area are included in three families—Epeiridae, Tetragnathidae, Theridiosomatidae—all formerly included in the Argiopidae (or Epeiridae). The present annotated list is represented largely by specimens in the author's collection, but also includes specimens in the collections of the Chicago Natural History Museum, the Chicago Academy of Sciences, Northwestern University as well as some in the private collections of Drs. Sewall Wright, Robert E. Gregg and Mrs. Elizabeth Moffatt.

The Chicago area may be considered a typical mid-western area with all types of habitats of such an area represented. Most conspicuous and unique is the Indiana-Michigan Sand Dunes area with its interesting series of biological communities. Various climax forest regions, prairies, flood plains, streams, lakes, tamarack bogs, and transitional areas are well represented.

Most of the records in this paper are from material whose identification is certain and do not include the immature specimens which are difficult to determine. I have not examined the collections of Mrs. Moffatt but have included information of this worker from her unpublished manuscript on the spiders of the Chicago area written in 1925. Since the death of Mrs. Moffatt the location of her collection is unknown and verification of her species is impossible. However, since many of them are easily recognized from the accompanying photographs, and since many of them were personally checked by J. H. Emerton, and also since no species recorded in her paper is absent from the author's collection, it is reasonable to assume that their determination was valid.

This paper is organized to serve not only as a check list but also as a key for identifying species found in the area. Therefore, it is recommended that anyone attempting to use the key should either be familiar with the use of spider keys or have access to Comstock's *Spider Book*, McCook's *American Spiders and their Spinning Work*, or Kaston's *Spiders of Connecticut*. Any one of these references has good discussions of key characters and most of the species concerned, though Kaston's book probably would be found to be the most useful.

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LOCALITIES

The Michigan area is the smallest state area investigated and includes only Berrien County. Five trips were made to Warren's Woods, a preserve, mainly of climax forest, but with a stream running through it providing some flood plain species. It is a few miles inland from Lakeside to which three trips were made. Lakeside includes some subclimax dunes as well as beach, foredune and intermediate associates. Dr. R. E. Gregg collected the specimens from Clear Lake and Mrs. Zora (Ivaska) Braddock collected the specimens from Coloma during a few weeks summer vacation.

The Wisconsin area was next most completely covered during the summer of 1938 with a period of about 6 weeks being spent in the Lake Geneva area. The Narrows, College Camp, Wychwood and the Fontana bog are all directly on the shores of Lake Geneva, largely in moist woods. Lakes Como and Delavan are nearby. Some of the Delavan collecting was done by Mr. Earl Wright and his family in the town itself. The Sugar Creek township collecting was from roadside sweeping of vegetation. The Lyons township bog as well as the Fontana bog are typical tamarack bogs. The Green Lake locality was collected by Dr. Garrett Hardin.

Some of the Indiana localities were very well collected. This is true of the Dune Acres or Mineral Springs bog area which was visited more than thirty times. Habitats there vary through all the types of associates and include a very old bog. Seven visits were made to the Coffee Creek flood plain a few miles from Chesterton. All collecting there was in the flood plain flats. Miller is another dunes area and was visited only a few times. It includes several associates with oak woods predominant. Mrs. Moffatt's collections in this area probably were in much the same types of habitats. Over fifteen trips were made to Ogden Dunes where the habitats are much the same as at Dune Acres but without the presence of bogs. The Sager's Lake collecting (done prior to 1935) was done in typically oak-hickory habitats. The Smith locality (northwest of LaPorte) is mainly a beech-maple climax with a very moist, nearly swampy, floor. More than a dozen trips were made to this place. Tremont, visited about a dozen times, is similar to Dune Acres but with subclimax and climax associates in greater abundance. Wilson (Dune Park), Beverly Shores and Pine are similar to the older dune areas

except that Pine consists of a larger series of alternating low narrow ridges and narrow ponds. These areas were visited not more than twice each. Wolf Lake and Hessville were collected by earlier workers, around 1910. Valparaiso and Hammond were collected by F. R. Elliott or reported by him as collected by Blatchley prior to 1932.

Remaining localities were in Illinois. Waukegan Flats (Beach) was visited approximately thirty times. This area includes sparse oak and pine associates, but is mainly of beach and meadow habitats. Pembroke township in Kankakee County was visited more than twenty times. This area is mainly black oak sand dune. Palos Park Forest Preserve, as well as most of the other Illinois localities, is typically an oak-hickory, maple area with interspersed prairies. The areas collected by Mrs. Moffatt could probably be described in the same broad way.

ABUNDANCE

Tables I and II record localities and the relative abundance of the species collected. Table II shows the number of specimens collected or examined. This listing probably shows the relative abundance best though the number of different places at which each species was found (as shown in table I) is also indicative of abundance. Using the method of indicating abundance so clearly presented by Preston (1948) does not help this analysis since systematic collecting with regard to making an accurate analysis of the abundance was not attempted (some common species were not collected every time they were seen). However, the general abundance tends, roughly, to follow the pattern of most groups. It might be pointed out that collecting with a view to also showing abundance would enhance any study of this kind tremendously and should certainly be encouraged of others working in such a field.

It may be pointed out with certainty, even from this meager data, however, that *Tetragnatha laboriosa*, *Neoscona arabesca*, *Argiope aurantia*, *Acanthepeira stellata*, *Argiope trifasciata*, and *Eustala anastera*, are among the commonest species of orb-weavers in the area. With some exceptions, also, the last twenty species roughly, could be called rare in this area.

The males are distinctly less common in the collection than the females since only 30 percent were males (562 specimens). Twenty-three percent (129) of the immature (589) and 33 percent (433) of the adults (1326) were males. These figures are included to show tendencies since all immature forms were not collected and easily identified species were not always collected. That is, collecting was selective to some extent. Usually all specimens were collected, so the figures should show some tendency, particularly as regards sex ratios. More complete collecting, done subsequently, shows that much less than 70 percent (1326 specimens) of a population are usually in the category of adults. The scarcity of adult males was probably due to the relatively shorter time that they lived after reaching adulthood. The data on the relative abundance of the two sexes, then, merely points out that males are usually collected about half as often as the females, though their total abundance may be quite different.

TABLE I.—Ecribellate orb-weaving spiders of the Chicago area.

| Species | No. of specimens collected | Males | | Females | | im. |
|---|----------------------------------|-------|-----|---------|-----|-----|
| | | im. | ad. | im. | ad. | |
| 1. <i>Tetragnatha laboriosa</i> | 638 | 34 | 204 | 109 | 284 | 7 |
| 2. <i>Neoscona arabesca</i> | 181 | 14 | 44 | 52 | 64 | 7 |
| 3. <i>Argiope aurantia</i> | 156 | 3 | 32 | 19 | 102 | 0 |
| 4. <i>Acanthepeira stellata</i> | 115 | 23 | 1 | 84 | 6 | 1 |
| 5. <i>Argiope trifasciata</i> | 109 | 10 | 22 | 20 | 57 | 0 |
| 6. <i>Mangora ornata</i> | 101 | 0 | 25 | 6 | 69 | 1 |
| 7. <i>Mangora gibberosa</i> | 81 | 0 | 37 | 2 | 41 | 1 |
| 8. <i>Eustala anastera</i> | 64 | 7 | 16 | 18 | 23 | 0 |
| 9. <i>Epeira trifolium</i> | 51 | 1 | 8 | 6 | 36 | 0 |
| 10. <i>Epeira marmorea</i> | 51 | 7 | 1 | 26 | 17 | 0 |
| 11. <i>Tetragnatha elongata</i> | 49 | 0 | 14 | 4 | 31 | 0 |
| 12. <i>Singa variabilis</i> | 45 | 17 | 2 | 21 | 5 | 0 |
| 13. <i>Leucauge venusta</i> | 41 | 2 | 0 | 6 | 25 | 8 |
| 14. <i>Epeira cornuta</i> | 34 | 2 | 3 | 9 | 20 | 0 |
| 15. <i>Neoscona sacra</i> | 28 | 0 | 2 | 0 | 26 | 0 |
| 16. <i>Epeira sericata</i> | 24 | 1 | 5 | 2 | 16 | 0 |
| 17. <i>Tetragnatha caudata</i> | 22 | 4 | 0 | 9 | 9 | 0 |
| 18. <i>Micrathena sagittata</i> | 21 | 1 | 2 | 3 | 13 | 2 |
| 19. <i>Neoscona pratensis</i> | 14 | 0 | 1 | 1 | 0 | 12 |
| 20. <i>Avaniella displicata</i> | 12 | 1 | 4 | 3 | 4 | 0 |
| 21. <i>Tetragnatha pallescens</i> | 12 | 0 | 2 | 0 | 10 | 0 |
| 22. <i>Larinia borealis</i> | 9 | 1 | 0 | 5 | 3 | 0 |
| 23. <i>Epeira thaddeus</i> | 9 | 0 | 0 | 8 | 1 | 0 |
| 24. <i>Tetragnatha straminea</i> | 6 | 0 | 3 | 0 | 3 | 0 |
| 25. <i>Pachygnatha</i> sp. | 6 | 0 | 2 | 0 | 4 | 0 |
| 26. <i>Epeira patagiata</i> | 5 | 0 | 0 | 0 | 5 | 0 |
| 27. <i>Araneus solitarius</i> | 4 | 0 | 1 | 1 | 2 | 0 |
| 28. <i>Metepeira labyrinthica</i> | 4 | 1 | 0 | 0 | 3 | 0 |
| 29. <i>Araneus gemmoides</i> | 4 | 0 | 0 | 3 | 1 | 0 |
| 30. <i>Theridiosoma gemmosum</i> | 3 | 0 | 0 | 0 | 3 | 0 |
| 31. <i>Epeira pignia</i> | 2 | 0 | 1 | 0 | 1 | 0 |
| 32. <i>Cyclosa turbinata</i> | 2 | 0 | 0 | 0 | 2 | 0 |
| 33. <i>Tetragnatha versicolor</i> | 2 | 0 | 1 | 0 | 1 | 0 |
| 34. <i>Cyclosa conica</i> | 2 | 0 | 0 | 2 | 0 | 0 |
| 35. <i>Micrathena gracilis</i> | 2 | 0 | 0 | 0 | 2 | 0 |
| 36. <i>Gea ergaster</i> | 1 | 0 | 0 | 1 | 0 | 0 |
| 37. <i>Conepeira mayo</i> | 1 | 0 | 0 | 0 | 1 | 0 |
| 38. <i>Cercidia promiens</i> | 1 | 0 | 0 | 0 | 1 | 0 |
| 39. <i>Meta menardii</i> | 1 | 0 | 0 | 1 | 0 | 0 |
| 40. <i>Singa keyserlingi</i> | 1 | 0 | 0 | 0 | 1 | 0 |
| 41. <i>Singa pratensis</i> | 1 | 0 | 0 | 0 | 1 | 0 |
| Totals | 1915 | 129 | 433 | 421 | 893 | 39 |
| Totals of each sex | | 562 | | 1314 | | |
| Total immature | | | | 589 | | |
| Total adult | | | | 1326 | | |

KEY TO FAMILIES, GENERA AND SPECIES OF ORB-WEAVERS

The following key has been made as complete and usable as possible without the aid of drawings. The figures in parentheses after each keyed species correspond with the number preceding the discussion of that species in the main body of the paper and should be an aid for locating the particular species. The genera and species under each subfamily are listed alphabetically for greater ease in locating. Finally, it might be repeated that the use of Kaston's paper will be of the greatest aid in final identification of specimens, particularly if they seem to be new species.

- 1a. Clypeus usually lower than height of median ocular area (MOA); eyes homogeneous in color 2
- 1b. Clypeus as high as, or more commonly higher than, height of MOA; femora without trichobothria, and tarsus IV without a sustentaculum; eyes silvery and dark colored; sternum broadly truncate behind; palpal organ very large, about three-fourths size of cephalothorax; paracymbium distinct but small; palpal tibia without apophysis; epigynum very large; abdomen high and rounded; small (about 2 mm.); female palp without claw; femur I about four times as thick as IV; chelicerae without stridulating area. Family Theridiosomatidae *Theridiosoma gemmosum* (1)
- 2a. Femora with trichobothria (at least one at base of femora I & II); boss of chelicera rudimentary or absent; chelicerae large and powerful, at least in most species Family Tetragnathidae
- 2b. Femora without trichobothria; boss present on chelicerae (rudimentary in *Meta*); chelicerae not unusually large Family Epeiridae

Family TETRAGNATHIDAE

Subfamily TETRAGNATHINAE

- 1a. Posterior femora with a double fringe of hairs on the prolateral surface of the basal half; epigastric furrow nearly straight, and epigynum well developed; chelicera with rudimentary boss *Leucauge venusta* (2)
- 1b. Posterior femora without such a fringe of hairs; epigastric furrow procurved, especially so in females, and epigynum lacking; chelicera without boss 2
- 2a. Endites slightly convergent and not dilated at the distal end; lateral eyes of each side contiguous or almost so; legs without spines and tarsi without accessory claws; abdomen oval and usually less than once and a half as long as wide *Pachygnatha* sp. (3)
- 2b. Endites parallel and more or less dilated at the distal end; lateral eyes of each side not contiguous (sometimes widely separated); legs spiny and tarsi with accessory claws; abdomen long and narrow, usually two or three times as long as wide (*Tetragnatha*) 3
- 3a. Lateral eyes of each side farther apart than the medians 6
- 3b. Lateral eyes not farther apart than the medians 4
- 4a. Lateral eyes of each side closer together than the medians 5
- 4b. Lateral eyes about as far apart as the medians; legs yellowish or white; abdomen silvery with dark reticulations; leg spines short, those on tibia I being not more than twice as long as the thickness of the tibia; male with the palpal tibia not much longer than the patella *Tetragnatha laboriosa* (6)
- 5a. In male, chelicerae shorter than cephalothorax, in female, little more than half as long; in both sexes fang evenly curved *Tetragnatha versicolor* (9)
- 5b. In males, chelicerae at least as long as cephalothorax; in female, almost as long; in both sexes fang sinuate *Tetragnatha elongata* (5)
- 6a. Abdomen prolonged into a distinct "tail" *Tetragnatha caudata* (4)
- 6b. Abdomen not so prolonged; spinnerettes terminal or placed just below the posterior tip of the abdomen 7
- 7a. In male, chelicerae as long as cephalothorax and without an unusually enlarged tooth on the promargin of the fang furrow, dorsal spur not bifid; in female,

- chelicerae extending almost horizontally from front of cephalothorax, and with the endites not hiding more than the tip of the folded fang *Tetragnatha pallescens* (7)
- 7b. In male, chelicerae shorter than cephalothorax, and with one very large tooth in the promarginal row; dorsal spur bifid; in females, the chelicerae are vertical or almost so, and the endites hide more than just the tip of the fang *Tetragnatha straminea* (8)

Family EPEIRIDAE

- 1a. Spinnerets elevated on a large projection and occupying a circular space limited by a thick flange in the form of a tube or ring; abdomen hard, flattened on the dorsum, and, at least in females, with a pair of caudal humps or spines, as well as, in some cases, lateral ones Subfamily Gasteracanthinae
- 1b. Spinnerets not surrounded by sclerotized walls 2
- 2a. Epigastric plates marked by transverse furrows; chelicera with well developed boss; usually with at least one sustentaculum on tarsus IV 3
- 2b. Epigastric plates without transverse furrows; chelicera with boss rudimentary; tarsus IV without a sustentaculum. Subfamily Metinae *Meta menardi* (10)
- 3a. Posterior eye row strongly procurved; ALE smaller than PLE; on each leg the tarsus and metatarsus together longer than tibia and patella together Subfamily Argiopinae
- 3b. Posterior eye row barely, if at all, procurved; usually straight or recurved; on each leg tarsus and metatarsus together not longer than patella plus tibia (except in *Metopeira* which can, however, be distinguished from the argiopinae by the fact that the lateral eyes are subequal) Subfamily Eperinae

SUBFAMILY ARGIOPINAE

- 1a. Eyes of anterior row almost equidistant, both sexes small (less than 1/5th inch); abdomen with a pair of dorso-lateral shoulder humps and several more behind these *Gea ergaster* (13)
- 1b. AME nearer to each other than to the ALE (about equidistant in male); adult females large, over half an inch long; males smaller, but over 1/5th inch long; abdomen without humps 2
- 2a. Vulva of female not divided by a septum; but the atrium of the epigynum extended into a broad, convex process, with a single cavity beneath; coloration mainly black with a yellow design (center stripe with two pairs of yellow spots); male much smaller and with dark color of a brown rather than black hue and more parallel-sided *Argiope aurantia* (11)
- 2b. Vulva of female divided by a septum into a pair of equal concavities; coloration silver with very fine black lines, and some yellow in the transverse bands; male much smaller but still mainly silver in color except for black spot above spinnerets *Argiope trifasciata* (12)

SUBFAMILY EPEIRINAE

- 1a. Tibia III bearing on its prolateral surface a double series of long, thin, feathery hairs (*Mangora*) 2
- 1b. Tibia III without such hairs 3
- 2a. Abdomen with several pairs (usually 3) of black spots on posterior half, sometimes connected by brownish transverse bands with no black line under femora or on cephalothorax *Mangora ornata* (32)
- 2b. Abdomen with three longitudinal stripes on posterior half with middle one extending farther forward than the side stripes (sometimes lacking or indistinct); also with several oblique stripes or spots on each side of the abdomen; thin black line under femora I & II, and on cephalothorax from thoracic grooves to eyes *Mangora gibberosa* (31)

TABLE II.—DISTRIBUTION OF ORBITERS OF T

| | Dune Acres | Smith Knackee Ch., Pembroke Twp. | Palos Park | Volo | Tremont | New Lenox | Coffee Creek | Ogden Dunes | Chicago | Miller | Coloma | Warren's Woods | Wolf Lake | Kankakee River | McGinnis Slough | Sager's Lake | Lakeside | Wilson (Dune Park) | College Camp (Lake Geneva) | Sage Bridge | Thornton | Gleer Ave. & 70th St. Deer Grove (Barrington) | Beverly Shore (Furnessville) |
|----------------------------------|------------|-------------------------------------|------------|------|---------|-----------|--------------|-------------|---------|--------|--------|----------------|-----------|----------------|-----------------|--------------|----------|--------------------|----------------------------|-------------|----------|--|------------------------------|
| 1. Neoscona arabesca | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 2. Argiope trifasciata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 3. Tetragnatha laboriosa | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 4. Argiope aurantia | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 5. Leucauge venusta | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 6. Eustala anastera | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 7. Epeira sericata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 8. Epeira trifolium | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 9. Epeira marmorea | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 10. Tetragnatha elongata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 11. Neoscona sacra | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 12. Acanthepeira stellata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 13. Mangora gibberosa | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 14. Araniella displicata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 15. Mangora ornata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 16. Tetragnatha straminea | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 17. Epeira thaddeus | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 18. Micrathena sagittata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 19. Epeira cornuta | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 20. Araneus solitarius | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 21. Epeira patagiata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 22. Cyclosa turbinata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 23. Tetragnatha versicolor | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 24. Tetragnatha caudata | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 25. Tetragnatha pallescens | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 26. Cyclosa conica | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 27. Neoscona pratensis | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 28. Theridiosoma gemmosum | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 29. Epeira pegnia | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 30. Larinia borealis | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 31. Metepeira labyrinthica | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 32. Pachygnatha sp. | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 33. Singa variabilis | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 34. Micrathena gracilis | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 35. Meta menardi | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 36. Gea ergaster | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 37. Araneus gemmoides | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 38. Conepeira mayo | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 39. Cercidia prominens | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 40. Singa keyserlingi | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| 41. Singa pratensis | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | x | | | | | |
| Total Species | 20 | 19 | 17 | 17 | 14 | 14 | 13 | 10 | 9 | 8 | 8 | 8 | 7 | 6 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |

OF ORBITERS OF THE CHICAGO AREA.

[illegible]

- 3a. Abdomen twice as long as wide in female, or almost so in male; attenuated at the base, and with longitudinal stripes above and below; MOA almost twice as wide in front as behind *Larinia borealis* (30)
- 3b. Abdomen shorter and not as above 4
- 4a. Approximately the basal $2/3$ to $5/6$ of abdomen covered by a shiny scutum which, however, does not obscure the pattern of markings; the anterior end of the abdomen overhangs the cephalothorax with a blunt point on either side of which are 3 to 5 spines set on dark elevations; leg formula 4123 *Cercidia prominens* (18)
- 4b. Abdomen not as above; leg formula 1243 5
- 5a. Abdomen hard, and with a thick, median, cone-like protuberance at the base, as well as lateral cones *Acanthepeira stellata* (14)
- 5b. Abdomen not as above 6
- 6a. Abdomen seen from the side truncate and elevated above the spinneretts, with or without prolongations; patella of male palp with only one dorsal apical spine 7
- 6b. Abdomen not so elevated, rather evenly rounded; patella of male palp with two spines, or with a single very fine bristle, in which case the palp is very long, as long as entire body 9
- 7a. Abdomen with a caudal tubercle, in females; more or less oval in outline, in males, not triangular; eyes on prominent tubercles and both eye rows recurved; scape of epigynum directed backwards as is usual (*Cyclosa*) 8
- 7b. Abdomen without a caudal tubercle; in both sexes more or less triangular seen from above; eyes not on prominent tubercles and posterior row slightly procurved; scape of epigynum directed forward *Eustala anastera* (29)
- 8a. Abdomen of female with a pair of dorsal tubercles and a long caudal projection; abdomen of male without tubercles or projections, coxa IV without short, thick spines, and endites without a pointed tubercle *Cyclosa turbinata* (20)
- 8b. Abdomen of female without dorsal tubercles and with caudal projection short; abdomen of male with a caudal tubercle, coxa IV with one or two stout spines and endites with a short, pointed tubercle on the lateral face *Cyclosa conica* (19)
- 9a. In both sexes, on all legs, the tarsi plus metatarsi longer than patellae plus tibiae; lateral eyes not on tubercles; venter with a median white band *Metepira labyrinthica* (33)
- 9b. Tarsus plus metatarsus not longer than tibia plus patella (except on legs I and II of some males) 10
- 10a. Epigynum without a free scape, though there may be a central lobe; legs with a few spines and relatively short; patella plus tibia I hardly, if at all, longer than the cephalothorax; integument shiny; body less than 5 mm. long (*Singa*) 11
- 10b. Either the cephalothorax has a free scape or if no scape is present the legs are longer; patella plus tibia I about $1\frac{1}{2}$ or more times as long as cephalothorax; integument not shiny 12
- 11a. Cephalothorax yellow with a little black between the eyes not extending to lateral pairs; abdomen variable, usually with double white stripe in middle and single stripe on each side with coloring dark (reddish to brown or black) in between *Singa pratensis* (38)
- 11b. Cephalothorax light orange with black around the eyes; abdomen usually black though variable with various light stripes and even light colored with dark spots in extremes *Singa variabilis* (39)
- 11c. Cephalic part of cephalothorax black blending into reddish brown thoracic part; abdomen with central white stripe and one low down on each side, stripes between of reddish-brown in middle and black at anterior and posterior end *Singa keyserlingi* (37)
- 12a. The thoracic furrow is distinct and in both sexes longitudinal; lateral eyes not on distinct tubercles (*Neoscona*) '3
- 12b. The thoracic furrow in females transverse, straight, recurved, or a circular pit; in males the furrow may be a pit with prolongations extending forward, backward

- and to each side; or if it appears to be longitudinal then the lateral eyes are on distinct tubercles 15
- 13a. Abdomen triangular to oval, broad anteriorly, epigynum elongate; males with tibia II straight or nearly so; femur I (as well as others) with a row of ventral spines; tibia II with numerous thick clasping spines all or nearly all the same length and arranged in two closely set rows along the prolateral edge, and a single long spine near the proximal end on the ventral surface *Neoscona sacra* (35)
- 13b. Abdomen uniformly oval 14
- 14a. Abdomen with a broad median brown band, on each side of which is a yellow stripe; between this yellow stripe and the margin of the abdomen on each side is a row of five or six black spots; male with coxa of fourth leg with a conical spur beneath *Neoscona pratensis* (36)
- 14b. Female with scape shorter than in *sacra*; dorsal surface with yellow band in middle or a series of yellow spots often, though the coloration is quite variable; male with no ventral spines on femur I; tibia II curved, the prolateral surface quite convex; with stout clasping spines arranged in a row along distal half of prolateroventral margin, with several longer spines near proximal end and with only a few ventral spines *Neoscona arabesca* (34)
- 15a. Abdomen smoothly rounded in front without shoulder humps (*Epeira*) 16
- 15b. Abdomen with shoulder humps at the anterodorsal angles (relatively inconspicuous in *Conepeira mays* males) (*Araneus*) 23
- 16a. Large spiders (over 1/3 inch) 17
- 16b. Small spiders (1/4 inch or less) 21
- 17a. Very large (1/2 to 3/4 inch long) 18
- 17b. Medium sized (1/3 to 3/5 inch long) usually associated with man's habitations .. 19
- 18a. Each lateral half of epigynum divided by a prominent furrow; tibia II of male thickened and armed with many short thick spines; ventral side of abdomen black in middle with a semicircular spot on each side; males with coxa II with a tubercle which may be short and rounded or long and pointed; tibia II much thickened and curved and armed with many short stout spines on the prolateral surface *Epeira marmorea* (23)
- 18b. Lateral halves of epigynum not divided by a furrow; tibia of second legs of male not thickened; ventral surface of abdomen lacking semicircular yellow spots; color usually all white above though pattern variable in many; legs annulate with orange and white; femora with ventral spines; scape widest at base *Epeira trifolium* (28)
- 19a. Scape finger-like; median apophysis of bulb of palpus more than twice as long as wide and split less than halfway to its base 20
- 19b. Scape flat and widened at the tip; median apophysis of the bulb of the palpus nearly as wide as long and split nearly to the base *Epeira patagiata* (24)
- 20a. Openings of spermathecae exposed in anterior part of epigynum; posterior lateral thickenings of epigynum nearly or quite meeting in the mid-line; in male, bulb of palpus with a long blunt terminal apophysis; legs long, tibia and patella I together more than twice, and metatarsus I about once and a half the length of cephalothorax *Epeira sericata* (26)
- 20b. Openings covered by a prominent lobe on each anterior lateral margin of epigynum; posterior lateral thickenings of epigynum prominently elevated; in male, bulb of palpus stouter at base but ending in a slender spear-like tip; legs shorter, tibia and patella I together less than once and a half, and metatarsus I less than, the length of cephalothorax *Epeira cornuta* (21)
- 21a. Abdomen oval with light yellow or crimson; on posterior half are three small oval black spots on each side (spots larger in the male) each spot surrounded by a lighter ring; the four muscle impressions in the cardiac region very conspicuous *Araniella duplicata* (22)

- 21b. Abdomen round and with spots and stripes other than as above 22
- 22a. Abdomen with dark stripes or rows of dark spots on each side; large dark area on ventral side surrounding light spot just back of epigynum; tibia II with few spines and none short as in *pegnia*; median apophysis with three distinct points; in females, femora and patellae on all the legs evenly bright orange *Epeira thaddeus* (27)
- 22b. Abdomen light brownish yellow with distinct folium basally occupied by two pairs of large white, yellow or pinkish spots behind which is a series of pairs of transverse black bands extending nearly to the tip of the abdomen; in male, tibia II with several short stout clasping spines on prolateral surface; median apophysis with two distinct points, in female; femora not evenly bright orange, but with at least one light and one dark ring *Epeira pegnia* (25)
- 23a. Large spiders; usually $\frac{1}{2}$ inch or more long 24
- 23b. Small spiders; usually less than 5 mm. long; no spines at all under femora; scape of epigynum relatively short, distally rounded and expanded to twice its width at base *Conepeira mayo* (17)
- 24a. Scape of epigynum triangular, as wide at base as long, color mainly tan *Araneus gemmoides* (15)
- 24b. Scape of epigynum finger-like; four or five times longer than its width at base and tapering little if at all. Male with small ventral conical tubercle on coxa II at least as long as wide; median apophysis of palpal organ relatively long *Araneus solitarius* (16)

SUBFAMILY GASTERACANTHINAE

- 1a. Abdomen with five pairs of spines approximately equal in size, of which one or two pairs at the caudal end may be hidden by a pair above them; abdomen of male three times as long as wide, and the spinneretts nearer the pedicel than the posterior end *Micrathena gracilis* (40)
- 1b. Abdomen narrow in front and broad behind, in male; terminated by two large conical pointed spreading tubercles, in the female; in addition, in female, two other pairs of pointed tubercles, one near base and the other between them and caudal tubercles, with some red in the pattern in addition to the other colors; spinneretts nearer caudal end than pedicel *Micrathena sagittata* (41)

DISTRIBUTION

Since it would add little to the usefulness of the paper to characterize the families, genera and species concerned, no more differentiating information than that included in the keys will be given except as such data will add to the ease of determining the species involved. There is only one species to be found in the Theridiosomatidae, three genera, including eight species in the Tetragnathidae, and four subfamilies of 15 genera and 32 species in the Epeiridae.

Family THERIDIOSOMATIDAE

1. *Theridiosoma gemmotum* (L. Koch.)—This species, also known as *T. radiosum*, is very interesting in its habit of snaring prey (Comstock). It is probably more common in the area than the collecting data indicate because it is a small spider not easily seen. It is restricted to moist wooded areas (collected only at two places—Smith and Warren's Woods—moist climax beech-maple woods). Mrs. Moffatt collected it only at Elgin, but it seems to have been common in that area.

The orb-web which is built by this species is small (less than six inches in diameter) having less than a dozen turns to the sticky spiral webbing. The web is placed vertically, or nearly so, and usually on the herbaceous or shrub strata on the more rigid branches and stems. The cocoon of this spider is more often seen than is the spider itself as it is

usually placed in a prominent place and in greater numbers than the spider. The cocoon is small (2-3 mm.) nearly spherical and tan in color. It is hung, usually, by two strands of silk from two twigs. This species is widespread throughout the country.

Family TETRAGNATHIDAE

2. *Leucauge venusta* (Walckenaer), Orchard Spider.—This species has been known also as *Epeira hortorum*. It is one of the most abundant species in the area. It seems to prefer situations which are moist to distinctly wet, as will be noted by the localities in which it has been found. From collecting data it is indicated that this species probably becomes mature in June. Its green and silver appearance and the usually horizontal web are distinctive features. The possession of a single or double fringe of long fine curved hairs on the external face of the basal half of the posterior femora separates this species, both mature and immature, from all other spiders in the Chicago area.

3. *Pachygnatha* sp.—The Chicago area species is probably not *xanthosoma* (C. Koch) but a new species. Holmquist (1926) lists *P. autumnalis* from the dunes. It is quite possibly the same species found by this collector. It has been found in the Chicago area only at Volo where it inhabited the floating mat of the tamarack bog. The life cycle, in the Chicago area, is not known as only adults have been found (in the spring). This genus is easily distinguished from *Tetragnatha* by its more compact form in contrast with the long thin aspect of that genus.

4. *Tetragnatha caudata* Emerton.—The long caudal development of *caudata* makes this species the most distinctive of the genus. It is also known as *T. lacerta* and *Eucta caudata*. It is readily identified by the tapering, almost worm-like, postanal prolongation. As is the case with *T. elongata* this species is found closely associated with water where it usually builds its web among reeds and grasses in or bordering creeks and ponds. It is common in the ecological areas where it is to be found.

5. *Tetragnatha elongata* Walckenaer, Stilt-legged Spider.—All individuals of this species, the largest of the genus which have been collected in the Chicago area, build their large webs across streams exclusively. The webs are often horizontal and as close to the water as practical though they may be found some distance up between bordering trees. The web is repaired as needed and only rebuilt when the spider moves to a new support. This species apparently matures in May though the similarity of all species in this genus makes it difficult to be sure of the species determination of the immature.

6. *Tetragnatha laboriosa* Hentz.—This species is the smallest of the genus and one of the most common and widespread throughout the country. In the Chicago area it ranks among the first in abundance. It is found in the herbaceous layer of the more open areas such as meadows where the web is built between plant stems. It seems to prefer dry situations, though it is found in moist areas too. This species apparently matures in mid-summer. The abundance of this species may not be as great as the figures indicate, as some of the immature specimens may have been of other species, and, the specimens were found in great numbers on a few occasions. Three hundred ninety-two of the specimens were collected in sixteen groups of more than ten males or females. A total of 443 specimens was collected on only nine trips, all of which were to Waukegan Flats, Dune Acres, and Kankakee County, leaving forty-two trips on which the remaining 195 specimens were found.

7. *Tetragnatha pallescens* F.O.P.-Cambridge.—This species appears to be more common than *T. straminea*, as it was found on more occasions and more specimens were secured. It is very similar to *T. straminea* in appearance and like that species is not distinguishable in the immature condition as far as is known. It seems to become mature in the late summer. As it was caught only in Black Oak Dunes it may have a preference for that type of terrain.

8. *Tetragnatha straminea* Emerton.—This species is not common in the Chicago area according to collecting, as the six specimens found were collected on only two occasions. It is apparently a moist woods species, found at Smith and Dune Acres. Mrs. Moffatt recorded it from Glen Ellyn, Wheaton, Aurora and Palos Park. It is not easily distinguishable from *pallescens* and *versicolor* except by careful microscopic examination.

9. *Tetragnatha versicolor* Walckenaer.—This species, formerly known as *extensa* (an European species not found in the United States), is not common in the area as only two specimens have been collected and those on two different occasions in the fall at Waukegan Flats and Beverly Shores. Mrs. Moffatt found it at Wheaton and Yorkville.

Family EPEIRIDAE

Subfamily METINAE

10. *Meta menardii* (Latreille).—The one specimen of this species collected was an immature one from the bog at Dune Acres. It was collected on June 15th. This is ordinarily a cave species and, therefore, since it wasn't collected in a cave, this record is questionable until other specimens have been found.

Subfamily ARGIOPINAE

11. *Argiope aurantia* Lucas, Black and Yellow Garden Spider or Golden Garden Spider.—This species has also been known as *Miranda aurantia*, *Epeira riparia*, and *Epeira cophinaria*. It is most commonly noticed by the inexperienced in the fall and suspected by them of being a new and startling species. It probably becomes mature late in the summer, usually not until August. The rest of the spring and summer it is too small to be noticed except by the expert. The adult females are very conspicuous in August and September when they are frequently brought into museums and other information centers for identification. They frequent meadows, gardens and any place where the herbaceous vegetation will support their webs and any place where it is fairly dry and not too shaded. The male, which is about a fifth to a tenth the volume of the female, shows the great sexual dimorphism in size so characteristic of the epeirids.

12. *Argiope trifasciata* (Forskål), Banded Silver Garden Spider.—This species is also known as *Metargiope trifasciata* and *Argiope transversa*. It is one of the commonest of the species in the Chicago area. Its silvery white banded pattern distinguishes it from *Argiope aurantia*, though its size, time of maturing, general distribution, etc., is apparently, though probably not actually, the same as for that species.

13. *Gea ergaster* (Walckenaer).—Only one immature specimen of this small typically southern species of epeirid has been found in the Chicago area. This was collected in the fall in the woods at Palos Park. It has been collected farther north around Madison, Wisconsin, so there is no reason to doubt this record though the species is certainly rare in the area.

Subfamily EPEIRINAE

14. *Acanthepeira stellata* (Walckenaer), Star-bellied Orb-weaver.—This species has also been described under the genus *Marxia*. It is one of the distinctive spiders of the area. It can be identified readily in any stage, as there are only a few other species with such spiny abdomens and all of them are more rare than *stellata* as well as distinctive in the other ways indicated in the key. Few adults were found, though the immature forms are very common. The species seems to be restricted to drier areas, particularly, as will be noted by the areas from which they have been collected (the meadows of Waukegan, Dune Acres, and Kankakee). Adults were found in late June through September, though only seven specimens were collected in contrast with a little over a hundred immature forms.

15. *Araneus gemmoides* Chamberlin and Ivie.—This is a rare species in this area. The four specimens were all collected at one time at Delavan. This record is possibly one indicating introduction because this is typically a western species. Its large size, tan color, and pair of basal humps are distinctive and should have caused it to be collected before if it were at all common.

16. *Araneus solitarius* (Emerton).—The European species *A. angulatus* has been considered until recently as being found in the United States. This is a large species with two humps at the base of the abdomen giving it an angular appearance. The web is often built high among tree branches in moist woods where it is not readily seen. Therefore it is probably more abundant than the four specimens collected by the author and the one collected by Mrs. Moffatt would indicate. Like *A. gemmoides* this is a large species with two large conical basal humps. Unlike *gemmoides* it is not nearly uniform tan but generally darker in color with vari-colored markings.

17. *Conepeira mayo* (McCook).—This species also has been called *A. miniatus*. Only one female of this small species has been collected. It is possibly a deep woods species in the area, as it was collected at Smith, Indiana. Its small size is possibly the reason for its not having been collected more. This species is similar to *A. displicata* in that it is small and white. However, it has a more or less distinct folium, and the paired black spots are four in number rather than three as in *displicata*.

18. *Cercidia prominens* (Westring).—Only a single female of this small species was collected (April 27, 1935) in the Volo bog mat zone. Its single dorsal scutum is an interestingly unique character.

19. *Cyclosa conica* (Pallas).—Only two immature females of this small species have been found in the moist beech-maple associates of Warren's Woods near Lakeside, Michigan, on May 2, 1941. It is a small spider with a small web and it has probably been overlooked frequently so that its abundance is surely greater than indicated. Mrs. Moffatt collected it at Wheaton, Elgin and Miller. Its outstanding characteristic is the one prominent irregular conical postabdominal tubercle. The webs of this genus are unique in that a string of carcasses of dead prey are wrapped in silk and fastened down the center of the web leaving a spot in the middle for the spider to rest and complete the straight line of possibly disguising material.

20. *Cyclosa turbinata* (Walckenaer).—Two specimens of this species were collected, both adult females. One was collected from her web in the Coffee Creek flood plain area near Chesterton on July 9, 1935 at night. The other was found August 2, 1938 at Dune Acres. The species is apparently not abundant though Mrs. Moffatt found more specimens of it than the author did. Its best distinguishing characteristics are the dorsal shoulder humps and a postabdominal projection (often reduced in the male).

21. *Epeira connota* (Clerck), Furrow Spider.—This species is also known as *foliata* and *frondosa* and has been included in the genus *Araneus* as is true of the following species also. Of the three species commonly found around human dwellings, this one has been more commonly collected in the woods away from habitations. For further discussion see *Epeira patagiata*.

22. *Araniella displicata* (Hentz).—This species has also been known as *cucurbitina* but seems to be distinct from that species which is European. It is not rare but has the peculiarity that only one specimen per trip was collected on twelve occasions. It seems to prefer woods of a fairly moist composition. The web of this species is very small and found on leaves of trees and shrubs, often in the space enclosed by a single leaf. The white or light color of the abdomen with three black spots on each side in both sexes and immature is a distinctive character.

23. *Epeira marmorea* (Clerck).—This is the *Aranea marmorea*, *A. gigas*, *A. conspicillatus*, and *Epeira insularis* of other authors. It is common in areas where the shade is good and the humidity fairly high and where it is cool, that is, particularly in the climax forests of the area. Most specimens seem to mature in late July. It builds a large web and is typically found in late summer, as the immature forms are small and not so commonly seen.

24. *Epeira patagiata* (Clerck).—This species is also known as *dumetorum* and *ocellata*. Of the three species of this genus commonly found around houses this is the least common. It was found on only five trips. The three species are most easily distinguished by the differences in epigyna and male palpi. The coloration differences are also distinctive but not easily described.

25. *Epeira pegna* (Walckenaer).—This is also known as *E. triaranea*. Only one male and one female were found at Joliet and Tremont. Mrs. Moffatt found a specimen at Wheaton. It seems to be an open woods spider.

26. *Epeira sericata* (Clerck), Gray Cross Spider.—It has been known as *undata* and *sclopetaria*. From present data this seems to be the most common house *Epeira* in the area. The web is a complete orb with a retreat of a dense sheet of silk built across an angle of the supporting structure.

27. *Epeira thaddaeus* Hentz, Lattice Spider.—The common name was given this spider as its retreat is covered by a latticework of silk. It has not been found commonly though

six collections in all have been made in the area. The web may be the *Zilla* type with a couple of the radii lacking spiral sticky webbing. It apparently matures in summer, as the immature specimens were found in June and July. *Araniella displicata* and *Conepeira mayo*, particularly in the immature condition, are not easily distinguished, primarily because they are similar in size and basically white or light colored; the variation is such that borderline immatures could be misidentified.

28. *Epeira trifolium* Hentz, Shamrock Spider.—The pattern on the dorsum of the abdomen gives this spider its common name. Like *E. marmorea* this species seems to prefer moist woods. A few immature specimens were caught in July and one in August. It is one of the largest epeirids.

29. *Eustala anastera* (Walckenaer).—This species is one of the commonest of epeirids in the area. It apparently matures in early summer as all May collections were of immatures while most later collections were adults. Both October collections contained immatures. The web is typical with nothing very distinctive about it. Though the species is found everywhere in the area it seems to prefer the wooded areas. The forward projecting abdomen and also epigynal scape and the subtriangular shape of the abdomen are good characters for distinguishing the species in the field. For further discussion see *Neoscona arabesca*.

30. *Larinia borealis* (Banks).—This distinctive long striped species superficially has a resemblance to *Tetragnatha* species in body form except for the lack of large chelicerae. It has been collected only on the south side of Chicago at Cicero and 70th streets, in the Kankakee dunes and the pine dunes area of Waukegan Flats. An immature male, five immature females, and three adult females were collected during July, August and October.

31. *Mangora gibberosa* (Hentz).—This small species with a very delicate but large closely woven horizontally placed, or slightly inclined, web generally is found in fairly dry situations. Its close relative, *M. ornata*, seems to prefer slightly moister areas. Of interest in this regard is the collecting done on July 29, 1939 when the entire population of *Mangoras* in a pine associates dune was *M. gibberosa*, while in a subclimax maple pocket less than a mile away all the specimens of that genus were *M. ornata*. Though not the most abundant species, this is still a very common one and to a lesser extent, this is also true of the other species. The possession of a cluster of long thin hairs on the anterior side of the tibia of the third legs near the base is characteristic of this genus only.

32. *Mangora ornata* (Walckenaer).—This species has been known more commonly as *M. maculata* but work by Chamberlin & Ivie has established the validity of Walckenaer's descriptions. This species is distinguished rather easily from the other *Mangora* by the series of paired black spots on the rear half of the abdomen (sometimes the spots are connected horizontally) in contrast with the three longitudinal stripes on the posterior half of the abdomen in *M. gibberosa*.

33. *Metopeira labyrinthica* (Hentz).—This is probably a woods species. It also seems to be more of a southern species. Its dorsal abdominal pattern is fairly distinctive while some of the diagnostic characters can be confused with the genus *Epeira*.

34. *Neoscona arabesca* (Walckenaer).—This species has been shown to be one of the commonest, most abundant, and most widespread of epeirids. It is probably commoner in woods but seems to build its large web wherever there is sufficient support for it without regard to humidity conditions. It is a larger species than *Eustala anastera* but probably about as common. Its color pattern, as is the case with *Eustala anastera*, is somewhat variable and hard to describe. The abdominal shape too is merely a generally rounded structure not as distinctive as that of *E. anastera* (Also see discussion of *Neoscona sacra*). Indications are that this species matures in mid-July though all stages can be found at most any time.

35. *Neoscona sacra* (Walckenaer).—This has been commonly known as *N. benjamina*. The main difference between this species and *N. arabesca* is the matter of size and shape of genitalia. This is a large species and not very common though certainly not rare. It also seems to prefer deep moist woods and builds a very large web, 4 or 5 feet between supports.

36. *Neoscona pratensis* (Hentz).—This uncommon species has been found only at Dune Acres and the Kankakee dunes and in a meadow of the flood plain of Hickory Creek near New Lenox. It seems to be more of a meadow or open woods spider. Its pattern of coloration distinguishes it from the other *Neosconas*. All but one of the fourteen specimens collected were immature.

37. *Singa keyserlingi* (McCook).—A single female of this species was collected on April 29th, 1933 at Sager's Lake near Valparaiso.

38. *Singa pratensis* Emerton.—One female of this species was captured on June 1, 1935 in the Kankakee dune area.

39. *Singa variabilis* Emerton.—This small species apparently prefers moist habitats. It was found on five different occasions at the Volo tamarack bogs and at Wolf Lake on the Indiana-Illinois border. It is the commonest species of the genus in the area.

Subfamily GASTRACANTHINAE

40. *Micranthema gracilis* (Walckenaer).—The members of this subfamily are probably more common than the data indicate but both species are definitely moist woods inhabitants. *M. gracilis*, a predominantly black or brown and yellow species, has been found only at Smith and Valparaiso.

41. *Micranthema sagittata* (Walckenaer).—This species is more colorful than *gracilis* having two prominent red-tipped spines at the apex of the abdomen. It is much more common than that species as it has been found at seven different localities. Apparently this species reaches adulthood in mid-summer.

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An Analysis of Stomach Contents of California Tide Pool Fishes

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The alteration of sandy bottom and tidepools, the varying depths of water, and the character of the marine vegetation along a rocky shoreline combine to produce diversified environments within relatively restricted areas. The fauna, both vertebrate and invertebrate, is correspondingly rich and varied, and adds to the ecological diversity. Under these conditions strong competition is expected, for each individual would exert some pressure, directly or indirectly, on its associates, especially in respect to food. One aspect of this complex relationship is the predator-prey relation between the fishes and invertebrates. The dependence of the fishes on the invertebrates may be one of the most important and effective factors determining the whole biotic relationship. The coexistence of various species of fishes may at the same time be determined by the degree of selective predation. The following observations are concerned with this complex subject of competition for food. They indicate that the different species of tidepool fishes feed selectively on the invertebrate prey and that only a small proportion of the invertebrate species are utilized.

METHOD OF COLLECTION AND ANALYSIS

Portuguese Bend, where the collections reported in this paper were made, is a well-known locality of the shore line of Los Angeles County where the coastal plain is interrupted by the Palos Verdes Hills which project into the ocean. The shore in this region is composed of a series of rocky points and outcrops. Tide pools of varying character occur throughout this area. The tide pools from which the fish sample studied was collected was approximately 69 feet in diameter and partially cut off from the surf by rocks. At least half of the pool was covered by dense patches of *Egorgia* and *Phyllospadix*, while many of the exposed rocks were covered with coralline algae. The bottom was predominantly bed rock with intermittent areas of sand. The shore exposed at low tide is of the same character except that the plants are sparse.

The invertebrate fauna of the pool embraces a considerable array of major groups: sponges, coelenterates, turbellarians, copepods, amphipods, isopods, decapods, gastropods, pelecypods, cephalopods, polychaetes, tunicates, and insects. Many of these are abundant in the habitat and are represented by more than one genus, and some genera by more than one species. Many species are represented by numerous individuals. The ultimate result is a rich and complex relationship of a large number of organisms.

The sample was obtained by poisoning the water with Cubé Root (Rote-

none content 5%) at approximately 1330 PST on March 12, 1949. Collection with dip nets continued from this time to approximately 1630 the same day. Soon after poisoning the tide was at the low level of minus 1.8 feet. The water depth in the pool ran to 5 feet at this time. The water temperature was approximately 14 deg. C. As the fish were collected they were placed in containers of 10% formalin. Soon after arrival at the laboratory a lateroventral incision was made into the body cavity to insure preservation of the internal organs and stomach contents. The author is indebted to Professor Boyd Walker and his assistants for aid in collection and identification of the fishes. The author is responsible for identification of the invertebrates found except in those instances where specialists were called on for identifications. Due credit is given in these cases.

Twenty-two species of fishes representing twenty genera were collected. Only *Oligocottus* (*O. rubellia*, and *O. snyderi*) and *Gibbonsia* (*G. elegans*, and *G. metzi*) were represented by more than one species. The abundance of each species as well as the sizes of the individuals of each species varied widely. The largest series were represented by *Gibbonsia elegans*, *Girella nigricans*, *Xerperes fucorum*, *Micrometrus minimus*, and *Clinocottus analis* in this order. About half of the species captured were represented by 3 individuals or fewer. The stomachs of 13 species were systematically examined and their contents identified. Particular attention was paid to those with larger numbers. These are reported below in detail. The data were recorded by size groupings, reflecting age classes, and in some cases by sex. After examination of the stomach contents the relative proportion by bulk of a particular food species was estimated. In some cases the individual invertebrates were counted. Digestion in the stomach and gut indicated that the invertebrates were being utilized for food. The stomach contents of nine species were not examined because they were represented by single individuals and were judged to be casual entrants or rare inhabitants of the pool.

The data that follow can be taken as representative only for this particular locality and season. The species of fishes present at higher tides might differ somewhat from those observed.

ANALYSIS OF STOMACH CONTENTS

HERBIVOROUS SPECIES

Two of the species in the collection were herbivorous. *Hypsypops rubicunda* was represented by a single half-grown male. The stomach contents consisted of algae, approximately 1/3 of which was coralline algae. The only animals found were several tunicates and sponges fastened to the algae. Although this fish is conspicuous when it is present, it is infrequent in this habitat. *Girella nigricans*, however, was abundant. The young of this species are pelagic, feeding presumably on pelagic copepods and similar organisms. Having attained a certain size they enter the tide pool habitat and gradually acquire the herbivorous feeding habit. The individuals in the collection were all greater than 100 mm in standard length. All had been feeding on various

soft algae (no coralline) and invertebrates were found in only two stomachs. One had a single amphipod, the other several copepods, which had probably been ingested incidentally. In order to ascertain the size of the fish during the transition from carnivorous to herbivorous habit, a supplementary sample was made with the help of Mr. Andreas Rehnitz in the summer of 1949. The stomachs of 30 individuals which had entered the intertidal habitat were then examined and the relative bulk of the food recorded under the following arbitrary groupings:

| St. Length | % Algae | % Copepods | % Amphipods |
|---------------|---------|-----------------|-------------|
| 50 to 70 mm | 50 | 40 | 10 |
| 78 to 85 mm | 80-90 | 10-20 | few |
| 86 to 100 mm | 96-99 | few | few |
| 101 to 187 mm | 100 | incidental only | |

CARNIVOROUS SPECIES

1. *Gibbonsia elegans* (72 specimens, 42-128 mm).—About 5 per cent of the stomachs were filled to capacity, about 30 per cent were essentially empty; most were approximately 35-40 per cent filled. The only apparent difference of prey in relation to the size of the fish was that the larger specimens had taken larger species of decapods.

ISOPODA

| | |
|--|----------------------------------|
| 51 <i>Cirolana harfordi</i> (31 in 42-62 mm group) | 1 <i>Pentidotea</i> (resecata ?) |
| 7 <i>Idothea rectilinea</i> | 1 unidentifiable flabelliferan |
| 2 <i>Pentidotea wosnesenskii</i> | 1 unidentifiable idotheoidian |

AMPHIPODA

| | |
|--------------------------|------------------------|
| 40 <i>Hyale frequens</i> | Unidentifiable remains |
|--------------------------|------------------------|

DECAPODA

| | |
|--|---|
| 7 <i>Spirontocaris picta</i> | 1 <i>Pagurus</i> sp. |
| 5 <i>Crangon</i> sp. | 2 unidentifiable macruran remains |
| 2 <i>Lophopanopeus frontalis</i> (in larger individuals) | 2 unidentifiable brachyuran remains (in larger individuals) |

POLYCHAETA

(det. by O. Hartman, USC)

| | |
|--|-------------------|
| 6 <i>Platynereis agassizi</i> (42-62 mm group) | 13 unidentifiable |
|--|-------------------|

GASTROPODA

| | |
|--|--|
| 3 <i>Fissurella volcano</i> (very small shells in smallest fish) | 1 <i>Acmea</i> (cona ?) <i>Barleeia bentleyi</i> (abundant) |
|--|--|

2. *Gibbonsia metzi* (17 specimens, 75-175 mm).—None of the stomachs were completely empty; most of them were 35-40 per cent filled. The stomachs of 2 of the larger fish were completely filled with decapods and polychaetes. Although amphipods were numerous in the smaller fish, they supplied only a minor part of the bulk.

ISOPODA

- | | |
|----------------------------------|-----------------------------|
| 1 <i>Pentidotea (resecata)</i> ? | 1 <i>Idothea rectilinea</i> |
| 1 <i>Pentidotea aculeata</i> | 3 unidentifiable |

AMPHIPODA

- | | |
|--|------------------------|
| <i>Eurystheus tenuicornis</i> (common) | 1 <i>Amphithoe</i> sp. |
| <i>Hyale frequens</i> (common) | 5 unidentified |

DECAPODA

- | | |
|-----------------------------------|----------------------------|
| 5 <i>Spirontocaris paludicola</i> | 1 <i>Mimulus foliatus</i> |
| 3 <i>Pagurus samuelis</i> | 1 <i>Pugettia gracilis</i> |

Unidentifiable brachyuran remains common

POLYCHAETA

9 *Platynereis agassizi*

3. *Xerperes fucorum* (43 specimens, 58-131 mm).—The stomachs and intestines of these individuals were more than 50 per cent filled, with the mean being about 70 per cent. At least 80 per cent of the bulk of the food in every stomach was composed of copepods, the remainder being amphipods. Isopods were insignificant in bulk.

COPEPODA

(det. by Paul E. Illg USNM)

- | | |
|---|---|
| <i>Zaus aurelii</i> (abundant) | <i>Procellidium fimbriatum</i> (common) |
| Unidentified, at least 6 species (common) | |

ISOPODA

(det. by Robert J. Menzies USNM)

- | | |
|-----------------------|--------------------------|
| <i>Pentidotea</i> sp. | <i>Cirolana harfordi</i> |
| <i>Mourea</i> sp. | |

AMPHIPODA

(det. by C. H. Shoemaker, USNM)

- | | |
|-----------------------------------|-------------------------------|
| <i>Hyale frequens</i> (common) | <i>Ischyrocerus</i> sp. (few) |
| <i>Amphilocus neapolitanus</i> | <i>Lembos</i> sp. (few) |
| (common but small) | Unidentified caprellids (few) |
| <i>Elasmopus antennatus</i> (few) | |

GASTROPODA

Barleeia bentleyi (1 individual completely filled, few in remainder)

4. *Micrometrus minimus* (25 females, 9 males).—Males (60-75 mm): Stomachs filled chiefly with several unidentified species of amphipods; 1 stomach completely filled with 5 individuals of *Platynereis agassizi* (Polychaeta); others 60-90 per cent filled with 12 individuals of *Cirolana harfordi* and 1 individual of *Pentidotea wosnesenskii* (Isopoda); no microgastropods.

Females (7 specimens 105-125 mm): Two stomachs were essentially empty; 5 were 35-40 per cent full. *Barleeia bentleyi* supplied more bulk than any other group, but the true bulk of digestible material could not be estimated because the bits of shell could not be separated from the body. Isopods, decapods and polychaetes supplied much of the bulk in the stomachs in which they were present, amphipods supplied only a small fraction of the material in each stomach.

- 6 *Pentidotea aculeata*
8 *Idothea rectilinea*
- ISOPODA
1 unidentified flabelliferan

- AMPHIPODA
20 *Allorchestes* sp. Few unidentified

- DECAPODA
1 unidentified Macruran

- GASTROPODA
1 *Acmea* scabra
1 *Acmea* sp. *Barleeia bentleyi* (abundant 120-125 mm,
fewer 105-110)

- POLYCHAETA
2 *Platynereis agassizi*

Females (18 specimens, 70-95 mm): 5 stomachs were essentially empty; 13 were filled 25-100 per cent. This group of smaller females had fed at this time not only on a lesser variety but also different kinds of invertebrates. The only species commonly taken by both groups was *Idothea rectilinea* and also *Platynereis agassizi*.

- ISOPODA
4 *Cirolana harfordi* 9 *Idothea rectilinea*
- AMPHIPODA
Hyale frequens (common) Unidentified sp. (numerous)
POLYCHAETA (anterior portions only)
(identified by O. Hartman, USC)
- 5 *Platynereis agassizi* 15 unnamed Cirratulids
9 *Marphysa sanguinea*

5. *Atherinops affinis* (19 specimens, 51-75 mm).—Stomachs about 60-70 per cent full. Proportions of groups about the same in each stomach. The insect larvae being seasonal, amphipods and copepods are probably of more importance throughout the year.

- INSECTA
Diptera 50 per cent bulk.
Larvae of *Coleopa* sp. (Coleopidae); det. by W. W. Wirth, USNM.
Coleoptera 30 per cent bulk.
Cercyon sp. (*Hydrophilidae*); det. by O. L. Cartwright, USNM.

- AMPHIPODA
Unidentified; 10-15 per cent bulk.

- COPEPODA
Unidentified; 5-10 per cent bulk.

6. *Clinocottus analis* (12 specimens, 60-110 mm).—No significant differences in stomach contents was apparent between either sex or size range. Stomachs of all were full.

- AMPHIPODA
Unidentifiable; insignificant in bulk.

- DECAPODA
1 *Pugettia gracilis* 1 *Betaeus harfordi*
9 *Spirontocaris picta* 3 unidentifiable Brachyuran remains
(most of bulk in 8 stomachs) 1 unidentifiable remains

- POLYCHAETA
4 unidentifiable remains in fish larger than 100 mm

7. *Oxyjulis californicus* (12 specimens, 93-161 mm).—Stomachs were completely empty except for a small amount of sand in the end of the intestine.

8. *Heterostichus rostratus* (5 specimens, 113-283 mm).—Stomachs about 50 per cent full. The stomach of the largest specimen contained the remains of several large decapods but no *Spirontocaris*. The others were filled chiefly with this species.

ISOPODA

4 unidentifiable Idotheoideans

DECAPODA

11 *Spirontocaris paludicola* Unidentifiable remains of large species

9. *Pimelometopon pulchrum* (1 adult male).—Comparatively rare in this habitat; stomach contents unidentifiable as to genus but consisting of crushed gastropod shells (1 *Haliotis cracherodii*) and a piece of fish or crab flesh which had apparently been scavenged. The intestine was completely filled with sand, coralline algae, shell bits and other detritis.

10. *Sebastes rastrelliger* (1 adult).—Stomach full. This species occupies a high link in the food chain, even though its members are few in this habitat. The only specimen in which the remains of small fish were found.

DECAPODA

3 *Spirontocaris* (*pieta* ?) 1 unidentifiable brachyuran

TELEOSTOMI

Small ribs with some flesh

11. *Scorpaenichthys marmoratus* (1 specimen, 165 mm).—Stomach about 75 per cent full.

DECAPODA

Remains of brachyuran

CEPHALOPOL.

Remains of an octopod

DISCUSSION

Of the twenty-two species of fishes collected, only two were definitely herbivorous, and only one of these species, *Girella nigricans*, was abundant. It was surpassed in numbers only by *Gibbonsia elegans*. The only other herbivorous species found, *Hypsypops rubicunda*, is of relatively little importance and occurs more naturally and in greater abundance in deeper water. Larger individuals of *Girella nigricans* also occur at lower depths, but individuals of the size range studied are apparently in an optimum environment at this level. With the great abundance of algae, it is interesting that only one common species of fish utilizes this food source directly, and then only as an adult. However, many of the invertebrates feed on the plants. Some of these are abundant and form the main food source for other forms of invertebrates and for many of the fishes.

All, except possibly one, of the remaining species of fishes examined, were carnivorous. The evidence indicates that there is apparently little competition between these species for food. Although two or more fishes may feed on the same invertebrate, the total prey of each species is limited and characteristic for that species. There is a selective predation which is guided, perhaps, by the behavior patterns of both predator and prey. This situation would lead to an optimum exploitation of suitable invertebrate food. (However, much of the invertebrate fauna is not utilized.) The types found most abundantly in the stomachs of the fishes were copepods, amphipods, isopods, decapods, polychaetes, and gastropods.

Copepods were abundant only in the stomachs of the eel blenny, *Xerperes fucorum*, where they formed the great majority of the bulk. They were typical of the harpacticoids which can be obtained in washings of marine plants, and which are very common in the eel grass and algae, the habitat of this fish. Since *X. fucorum* has a small mouth and no straining mechanisms, these minute crustaceans must be taken singly and repeatedly. However, this fish apparently has an exclusive food source.

Amphipods were commonly found in seven species of fish. In all cases except one they were apparently supplementary to other forms, and composed only a minor part of the stomach contents. They did, however, form the major bulk of the food for the small females and the males of *Micrometrus minimus*, the least perch. The amphipods taken in greatest abundance by this species (and by *X. fucorum* as well) were *Hyale frequens* and *Amphilocheus neapolitanus*. These are littoral forms which live in the algae. Both are common in *Phyllospadix*, while *H. frequens* is also found commonly on coralline algae. *A. neapolitanus* is a very small species and did not provide as much of the bulk of the stomach contents as *H. frequens*.

Several species of idotheoidian isopods were taken by a number of the fishes; however, they are of minor importance in the total diet of any species. They are common inhabitants of the kelp and eel grass, and *Pentidotea wosnesenskii* also occurs commonly in mussel beds. On the basis of their abundance it could be expected that they would supply a greater proportion of the food of the fishes which prey upon them (the large female *M. minimus*, *Gibbonsia elegans*, and *G. metzi*). They are apparently well camouflaged, however, and are difficult to see in the kelp and eel grass.

The only other isopod frequent in the stomach contents was the small flabelliferan, *Cirolana harfordi*. It was taken by small fish and was abundant only in the smallest specimens of *Gibbonsia elegans*. It was much rarer in the stomachs of the males and small females of *M. minimus* and in *Xerperes fucorum*. This isopod is found commonly under rocks in the mid-tide zone but is also common in other zones.

Decapod crustaceans supplied much of the bulk of the stomach contents of the larger species of fishes and of the larger individuals of some of the smaller species. Six of these fishes apparently obtain the major part of their food by preying on these large crustaceans. They were taken almost exclusively by the tide pool sculpin, *Clinocottus analis*, supplied practically all the

bulk in *Heterostichus rostratus*, and were abundant in the long list of prey of *Gibbonsia elegans* and *G. metzi*. The most important of the larger crustaceans were the two species of hump-backed shrimp, *Spirontocaris paludicola* and *S. picta*. One or the other of these shrimps was found in significant numbers in all of the large carnivorous fishes. *Spirontocaris picta* supplied at least half of the bulk of the stomach contents of *Clinocottus analis*, and a significant portion of the bulk in *Gibbonsia elegans*. *S. paludicola*, on the other hand, was of importance in the case of *G. metzi* and *Heterostichus rostratus*. The only other macruran decapods identified were *Betaeus harfordi* and *Crangon* sp., and they were rare.

Several species of polychaete worms were very abundant. *Platynereis agassizii* was found exclusively in the stomachs of some individuals of *Gibbonsia elegans*, *G. metzi*, and *Micrometrus minimus*. This species builds colonial mucous nests in kelp holdfasts. It is apparently easy prey, not only because of its common occurrence in four species of fish but also because the stomachs of the individuals which had been feeding on them were completely filled.

The other polychaete species, *Marphysa sanguinea*, and an unnamed cirratulid were much smaller and were found only in the small female group of *Micrometrus minimus*. These species are burrowing forms inhabiting shale and clay substrata. Dr. Hartmann suggests that the fishes that feed upon these polychaetes must have feeding habits that involve swimming slowly over the bottom and biting off the anterior ends of the worms as they crawl from their burrows.

Microgastropods (*Barleeia bentleyi*) were found to be of major importance in the stomach contents of the large female group of *Micrometrus minimus* and in *G. elegans*. None of these minute shellfish were found in any of the smaller females or males of *M. minimus*, but they were common in all specimens of *G. elegans*, and a number were found in one specimen of *Xerperes fucorum*. The lot of shells taken from the stomachs proved to be the second collection of this species, and showed that somewhere within the range of large female *M. minimus* it is common.

Larger gastropods were rare in occurrence. Several young limpets (*Fissurella volcano*, *Acmea cona*(?), and *A. scabra*) were found in some individuals of *M. minimus* (large females), and *G. elegans*, and one black abalone (*H. cracherodii*) was found in *P. pulchrum*. Although no vertebrate predators of the limpets have been known, it is recognized that the sheephead (*P. pulchrum*) commonly feeds on abalone.

The number of species of invertebrates found in the stomach contents of these fishes is remarkably low in view of the total number present: 8 (+) copepod species, 9 (+) amphipod species, 6 isopod species, 8 (+) decapod species, 3 polychaete species, 5 gastropod species, 1 cephalopod species, 1 dipteran species, and 1 coleopteran species were recognized, a total of over 42 species. However, three obvious sources of errors of analysis should be recognized. Some invertebrates may have been present but unrecognizable because of disintegration and digestion; a common prey of some of the fish species might have been taken by them just previous to the collection due to cyclical

activity or some other phenomenon; and, finally, the sample of some of the fish species is too small for positive conclusions. Nevertheless, a number of the species preyed upon are rare in the stomach contents, although they are abundant in the habitat. The hermit crabs (*Pagurus*), the shrimps, *Betaeus harfordi* and *Crangon* sp., and the limpets, *Fissurella* and *Acmea*, are examples of very common invertebrates that were taken by only a few fishes. It is probable that these animals are less vulnerable or less desirable than the more common prey.

Most of the common and conspicuous invertebrates of the pool are apparently not preyed upon at all by the fishes present. Pelecypods, coelenterates, chitons, tunicates, sponges, turbellarians, echinoderms, and most of the gastropods and polychaetes are conspicuously absent. Some of these are known to have other invertebrate predators but little is known concerning predation for most of them.

The size of the prey was correlated in general with the size of the fish. The larger individuals of a species of fish usually contained the larger individuals of a species of invertebrate, as well as larger invertebrate species not taken at all by the smaller fishes. For example, full-sized adult *Idothea rectilinea* were taken by the large individuals of both species of *Gibbonsia*. Smaller *I. rectilinea* were taken by the smaller individuals. Very small *Idothea* (probably *rectilinea*) were taken by *Xerperes fucorum*, which is a still smaller fish. Full grown crabs, such as *Lophopanopeus frontalis* and *Mimus foliatus*, are much too large to be swallowed by either species of *Gibbonsia*. However, two of the largest specimens of *G. elegans* (128 mm) contained young *L. frontalis*, and the largest specimen of *G. metzi* (175 mm) contained a half-grown *M. foliatus*. The hump-backed shrimps of the genus *Spirontocaris* were found whole in the stomachs of five of the species of fishes, but usually only in the larger individuals of each species.

An analysis of the comparative ecology of the two species of *Gibbonsia*, as determined by their stomach contents, in general corroborates the observations of ichthyologists that *G. elegans* inhabits a slightly higher (but definitely overlapping) level than *G. metzi*. Many of the invertebrate prey were taken by both species, but of those taken exclusively by *G. elegans*, most were forms usually found in the mid-tide zone (*C. harfordi*, *F. volcano*, *Acmea* sp., *P. wosnesenskii*), while those taken only by *G. metzi* are deeper water forms (*M. foliatus*, *P. gracilis*, *E. tenuicornis*, *Amphithoe* sp.). In addition, the majority of the bulk of the stomach contents in *G. metzi* was composed of deeper water forms than the majority of the bulk in the stomach contents of *G. elegans*.

In the case of *Micrometrus minimus* three groupings were made, originally on the basis of size and sex. The stomach analysis proved that these three groups also differ significantly in feeding habits. In the large female groups (125 mm-105 mm) a significant amount of bulk was provided by two species of kelp-dwelling isopods, *Pentidotea aculeata* and *Idothea rectilinea*, while amphipods were abundant. In the small females (95-70 mm) *I. rectilinea* was also present but amphipods and polychaete worms were much more abundant. In the males (75-65 mm) most of the bulk was composed of amphipods.

Pods. Perhaps the size of the idotheoidions limits the smaller individuals to smaller prey such as amphipods; however, the polychaete *P. agassizi* is larger than the isopods and was more common in the smaller fishes. Thus it is possible that the larger females of this species range higher in the kelp than the small females or the males.

SUMMARY

Twenty-two species of fishes were collected from a tide pool at Portuguese Bend in Los Angeles County, California. The stomachs of 13 species were examined and the relative proportions of the food species were estimated. Invertebrates were found to be the chief source of food in ten of these species while two were found to be herbivorous.

So far as this sample can be taken as representative of the ordinary diet of these fishes, it would appear that the principal food differs with different species, in part because of size differences, and in part because of differences of feeding habits. The principal food of different size classes of some species may also differ.

A relatively small proportion of the invertebrate species common in the pool forms the prey of the fishes.

The evidence suggests that although numerous species of fishes may be present in the same pool, they are not necessarily directly competitive for food, but that a competitive balance exists between them.

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Experiments on the Senses of Taste and Smell in the Bob-white Quail (*Colinus virginianus virginianus*)¹

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The literature on olfaction and gustation in birds is contradictory and confusing. Birds have been described as anosmatic, (Audubon, 1835; Bachman, 1834; Soudek, 1927; Marples, 1931; Walter, 1943) microsmatic, (Darwin, 1834; Beebe, 1909; Strong, 1911; Wagner, 1939) and possessing a keen sense of smell (Gill, 1904; Benham, 1906; Zahn, 1933; Salverda-Ter-Laag, 1936; Nolte, 1927). The gustatory powers of birds have been similarly described (Engelmann, 1934, 1937, 1940; Stietz, 1934; Salverda-Ter-Laag, 1936). This study was undertaken, therefore, to determine whether the bob-white quail (*Colinus virginianus virginianus*) could respond to olfactory stimuli, and to interpret the gustatory sense in more understandable terms by comparing this sense with that of other animals.

The bob-whites used in the experiments were donated by the Pennsylvania Game Commission. The birds were housed indoors in regular game commission cages, 24" x 12" x 12" in size. Rations used were the same as those fed to game-farm bob-whites.

SENSE OF SMELL

Experiment I.—The purpose of this experiment was to determine whether the bob-white quail could be trained to associate the odor of coumarin with food. Coumarin was chosen for the experiment, because the chemical formula is known, and it can be used in a purified form. The apparatus consisted of a circular experimental pen 3 feet in diameter made of chicken-wire and three feeders made from "No. 3" fruit-juice cans, painted with green enamel to make them uniform in appearance. The top of each can was removed and a hole 1" in diameter cut into the side, about 2" from the top. A cheese-cloth packet containing coumarin was taped to the inside of one can, and cheesecloth packets containing quail mash and cracked corn were taped to the insides of the other two cans. Each feeder was then inverted over a small pill box. The pill box covered by the coumarin feeder contained cracked corn and quail mash, the other boxes were empty. With the feeders in place, a hungry bob-white was introduced into the pen and the bird's response to this situation noted.

The birds had been accustomed to the odor of coumarin by adding it to

¹ This is part of a thesis submitted to the Graduate Faculty of The Pennsylvania State College in partial fulfillment of the requirements for the degree of Master of Science. I wish to express my thanks to Drs. H. W. Frings and E. H. Dusham, of the Department of Zoology and Entomology, for their helpful suggestions and guidance.

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their food for 8 days before the beginning of the experiment. Nevertheless, they seemed afraid of the feeders and would not investigate their contents. This behavior continued even after food had been placed in all feeders and corn had been placed at the feeder entrances. To force the birds to adjust to the new environment, each bird was starved for 12 hours and placed in the experimental pen for one day. All but 2 birds fed under these conditions; these birds fasted 36 hours before accepting food from the experimental feeders.

Now, however, all the experimental birds fed from the feeder nearest the quail cages, and spent most of the time in escape efforts. This seemed to be due to the fact that the "covey" was within sight and hearing range. The experimental pen was accordingly placed in a room separated from the stock quail cages, and the activities of the birds were viewed through a window. The calls of the bird being tested could be heard by other quail and vice-versa, but this had little effect since the birds could no longer see each other.

With the birds accustomed to the experimental situation, the training program was initiated. The time required for each bird to locate the correct feeder was recorded, to be used as a measure of learning. It became apparent, however, after a few trials, that this failed to indicate the true progress, since it included all "freezing" and escape efforts of the birds. Therefore, only time spent by the bird in what was believed to be efforts to secure food was recorded. This became regularly shorter as the birds progressed. Errors (i.e., attempts to feed from feeders without coumarin) were recorded, but proved difficult to interpret.

When the birds found the food with regularity, the test conditions were imposed. All food was removed from the feeders, and the birds' responses noted. A test was considered positive if a bird showed a definite preference for the coumarin feeder in spite of the absence of food. The tests varied in time. If a bird repeatedly put its head into the coumarin feeder within a short time the test was discontinued and the result deemed positive. If a bird was slow and indecisive in choosing a feeder, the correct and incorrect choices were recorded. If the correct choices predominated the result was considered positive; if the bird did not favor any particular feeder, or favored a dummy feeder, the result was considered negative.

Only 2 of 8 birds failed to finish the training trials and the actual tests. The other 6 quail obviously associated the odor of coumarin with food, as clearly evidenced by their repeatedly seeking the feeder thus scented. To determine whether the quail distinguished the coumarin-feeder by visual cues, the original coumarin-feeder was deodorized and made into a dummy feeder and a dummy feeder was scented with coumarin. The new coumarin-feeder immediately became the object of attention by the quail.

Summarizing the results of the training and testing trials, the following conclusions were reached: (1) the bob-white does not train easily to an apparently unfamiliar stimulus such as odor; (2) the training program is time-consuming because of the reactions of the birds to a strange situation;

(3) all birds, with the possible exception of two, indicated a definite association of food with the odor of coumarin.

Experiment II.—In this experiment the birds were offered 2 foods, one repellent, the other edible, one of which was marked with the odor of coumarin. Sixteen bob-whites were divided into 2 test groups of 4 cages each, with 2 birds in each cage. Group A was offered a choice between scratch grain with coumarin and scratch grain with NH_4Cl ; coumarin thus marked the acceptable food. Group B was offered a choice between scratch grain alone and scratch grain with both coumarin and NH_4Cl ; coumarin thus marked the unacceptable food. Kitchen match-box holders, with $\frac{1}{4}$ " mesh screen covering the hopper opening, were used to hold the food. The position of the feeders was changed daily, and the consumption of grain from both feeders was recorded in grams. The experimental diet was the only food received by the birds during the tests.

Preliminary tests were performed with Group A to select a concentration of NH_4Cl which would repel the birds. It was found that 20 ml. of 4N NH_4Cl mixed with and allowed to dry on 100 gms. of scratch grain was repellent. Thus the NH_4Cl treated scratch grain used in the tests contained 4.28 gms. of NH_4Cl per 100 gms. of scratch grain.

Group A was tested to see whether the odor of coumarin influenced food choice, using scratch grain without NH_4Cl . In all trials the natural scratch grain was favored over the coumarin scented grain. This same group, however, found NH_4Cl more repellent than coumarin, when confronted with a choice between scented grain and NH_4Cl treated grain. As soon as the NH_4Cl was removed, however, the birds ate more untreated grain. Training was thus not involved in this experiment, since the birds were obviously testing both foods daily, and eating the most acceptable. The results do show, however, that the bob-white can distinguish between grain bearing the odor of coumarin and naturally scented grain.

In Group B, with NH_4Cl and coumarin in one feeder and untreated grain in the other, only a few grains of treated food were consumed. When NH_4Cl was removed from the coumarin feeder, with the coumarin still present, the same results were obtained. The odor of coumarin thus was either used by the birds as a warning, or its repellent effect was reinforced by the NH_4Cl .

The fact that coumarin proved repellent to the birds was quite unexpected. This poses an interesting question: what odors, if any, are acceptable to the bob-white? Would the bob-white, for example, reject acceptable food if it bore any unfamiliar odor? Further tests of odor preference and ability to distinguish between odors should be made. Dambach et al. (1948) found that pheasants were not repelled by terpene mercaptan, ground naphthalene, commercial kerosene and phenol soap, and Hill (1905) found that turkeys did not discriminate between two piles of food, one of which contained an odor. Carrion-eating hawks will accept fresh meat and malodorous rotting flesh with equal relish. Possibly an unusual odor in food which is otherwise

acceptable is not repellent to these birds as it is to the bob-white. The food habits of different birds vary widely, and odors which are attractive to or ignored by one species may be repellent to another.

The present experiments show that the bob-white possesses an olfactory sense. The acuity of this sense was not measured in quantitative terms, nor can any valid comparisons be made between it and the olfactory powers of other animals. However, it may be suggested that olfactory stimuli probably influence the food choice of this bird.

SENSE OF TASTE

Sixteen birds were tested in groups of 2 per cage. Each cage had 2 stoppered graduated cylinders with bent glass tubes fastened in an inverted position on the side. One contained water, the other a test solution. The birds quickly learned to peck the glass tubes to secure the liquid within. Each day the amounts of water and test solution were recorded, and a new test set up. To secure net consumption, 4 ml. were subtracted from the total consumption of both test solution and water, because this was found to be the average amount lost from the graduated cylinders through evaporation and agitation by the birds. The position of the test solution was alternated with the water daily. The responses to NaCl, CaCl₂, NH₄Cl, KCl, LiCl, HCl, and sucrose were tested in this manner.

Six concentrations each of the 5 chloride salts were chosen as suitable by preliminary tests and each written on a slip of paper. Each day one slip was drawn for testing, and when all 30 concentrations were drawn, this procedure was repeated. This system of randomization was used to obviate possible fatigue to an ascending series of concentrations of a single salt. Upon completion of this 50-day test, some tests were repeated if deemed necessary. The acid and sucrose concentrations were offered to the birds in direct sequence from the lowest to the highest concentration used.

The results of this experiment are presented in Table I. The median rejection threshold would be the concentration at which 50% of the birds rejected the test solution. When the intake of the test solution is 25% of the total intake, it is logical to assume that half the birds are not taking the test concentration, or all birds have been sufficiently stimulated to reduce the intake of the test solution to half. The metallic cations, as chlorides, form a stimulation order: $\text{Na}^+ < \text{Ca}^{++} < \text{K}^+ < \text{NH}_4^+ \leq \text{Li}^+$. The rejection of Li^+ by this animal is interesting, for Frings (1948b) found it less stimulating than Na^+ for *Eacles* and the rabbit. However, the stimulating properties of the other ions except H^+ are similar to those found by Frings for *Eacles* and the rabbit (1948b), the cecropia moth (1945), *Tabanus* (1946), and *Periplaneta* (1946). Fabian and Blum (1942) found Na^+ less stimulating than Ca^{++} for humans. The acceptance of HCl at a 0.3 level is surprising, and may seem to indicate a low level of sensitivity. The results with Li^+ , however, belie this.

TABLE I.—Results of tests in which quail were offered a choice between water and solutions of substances listed. The percentages of total fluid intake comprised by the test solutions at the normalities indicated are listed. The 50% level indicates no differentiation. Less than 50% shows rejection of the solution and greater than 50% a preference for the solution. The median rejection threshold is the 25% level. "No. of Tests" refers to the total number of tests at all concentration of the substance listed.

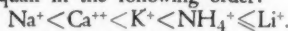
| Substance | No. of Tests | Percentage consumption of the test solution at normality: | | | | | | | | | | |
|--------------------|--------------------|---|-----|-----|-----|-----|-----|------|-----|------|-----|------|
| | | .6 | .5 | .4 | .3 | .2 | .1 | .075 | .05 | .025 | .01 | .005 |
| NaCl | 159 | 1% | 17% | 30% | 21% | 37% | 54% | | | | | |
| CaCl ₂ | 142 | | 6% | 14% | 21% | 19% | 35% | 58% | | | | |
| KCl | 156 | | | | 5% | 16% | 44% | 41% | 51% | 43% | | |
| LiCl | 160 | | | | | 4% | 3% | 33% | 40% | | 36% | 66% |
| NH ₄ Cl | 206 | | | | | 2% | 17% | 37% | 23% | 41% | 49% | |
| HCl | 144 | | 8% | 18% | 13% | 18% | 21% | 29% | 51% | | | |
| Sucrose | 224 | | | | 50% | 42% | 56% | | 61% | 63% | 73% | 60% |

The ready acceptance of sucrose at strong concentrations and preference for the sugar at low concentrations is also surprising. The amount of sweet food the quail encounters in nature is probably small, yet this bird showed a preference for a sweet solution over water up to 0.4 M. However, Frings (1948a) states that all animals he has tested accept sucrose. Richter et al. (1940) found that the taste threshold for sucrose for rats was 0.0146M., and for humans 0.012M. both these acceptance thresholds are higher than that found for the bob-white. This would indicate that the bob-white is more sensitive to sucrose than the mammals tested by Richter.

This experiment shows that the bob-white quail responds to the gustatory stimuli tested in much the same manner as other animals and appears to possess a comparable sensitivity. These results are certainly not in accord with the general opinion on gustation in birds. Actually, however, there are morphological (Moore and Elliott, 1940), as well as experimental evidences which lead us to expect a quite well developed sense of taste in birds. The often peculiar food habits of birds have probably contributed to the belief that birds have this sense poorly developed.

SUMMARY

Bob-white quail can be trained to associate the odor of coumarin with food. The bob-white is a difficult animal to train to respond to an odor; possibly odor is an unfamiliar stimulus, or perhaps the bob-white would be difficult to train to any sensory cue. When coumarin is added to the food of the quail, food consumption is markedly reduced. The birds were offered daily a choice between a test solution and water. Five metallic chlorides, HCl and sucrose were used for the test solutions. The cations as chlorides were rejected by the quail in the following order:



This order is similar to that reported previously for other animals, except for Li⁺. HCl was accepted in concentrations as high as 0.4 N. Sucrose

solutions are readily accepted and even preferred over water by the bob-white. These experiments indicate that both the odor and taste of a food probably influence the food choice of this animal.

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Seasonal Variation of Some Limnological Factors in Irondequoit Bay, New York*

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During the summer of 1939 a series of samples was taken in the deeper part of Irondequoit Bay as a part of the general Biological Survey of the Lake Ontario Watershed conducted by the New York Conservation Department (Tressler and Austin, 1940). The results of this mid-August sampling indicated a high degree of productivity and extreme stagnation conditions, which prompted the continuation of these studies during the following year. An extensive program of independent investigation was begun in September 1939 and was continued at monthly intervals until June 1940, when all three authors moved permanently from the state and as a consequence the work had to be discontinued. The present paper deals with the seasonal cycle in the bay from August 15, 1939, to June 13, 1940.

Irondequoit Bay is the third New York lake to be studied throughout the entire year; Cayuga Lake was investigated by Burkholder (1931) and Chautauqua Lake by Tressler, Wagner, and Bere (1940). Cayuga Lake is a large, deep oligotrophic lake and can not be directly compared with the much smaller, highly eutrophic Chautauqua Lake and Irondequoit Bay. The two latter bodies of water offer an interesting comparison in their varying abilities to free their waters of the results of extreme bottom decomposition, which is augmented, in the case of Irondequoit Bay, by pollution brought in by Irondequoit Creek.

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Myxophyceae; Mr. Paul Conger, Carnegie Institution and Dr. Ruth Patrick, Philadelphia Academy of Natural Science, *Diatomeae*; Dr. Noe Higginbotham, University of Washington, *Chlorophyceae*.

HYDROGRAPHY

Irondequoit Bay lies at the eastern outskirts of the city of Rochester, New York, and is connected by a shallow, narrow outlet with Lake Ontario. Both bodies of water, at an elevation of 75 meters above sea level, are almost entirely separated from each other by a wide bar over which the lake shore highway runs. Geologically, Irondequoit Bay lies in the Niagara limestones through which the Genesee River cut its way during late Mesozoic or Tertiary times. The history of the region in which Irondequoit Bay lies forms an interesting story and is fully set down by Fairchild (1928) from which the following brief account has been taken.

From Cambrian to Devonian times, the whole region was covered by shallow interior seas, during which time thousands of feet of sediments were deposited. These sediments at Irondequoit Bay at the present time include the Queenston shales along the shores of Lake Ontario; the Medina red sandstone above this, followed by the Clinton shales and limestone. The uppermost layer is known as the Irondequoit and is composed of limestone and shale. The Queenston shales belong to the Ordovician period, the remainder to the Silurian. South of the head of the bay, the Lockport dolomite outcrops. These strata have a slight dip of about 40 feet to the mile in a southward direction. They have been exposed to the air and to erosion by water and ice since the end of the Devonian.

Until early Tertiary the direction of stream flow in New York was to the south. Following this time, due to a number of factors (i.e. changes in elevation of the land, form of the land surface, climate, and the influence of the hardness of the rocks cut through by streams), the Genesee River was changed to a northerly direction of flow, where it formed a tributary to the great Ontario River. This large river flowed through the center of what is now Lake Ontario in either an easterly or westerly direction and had captured the Genesee River, a river much larger then than it is now. The Ontario River is responsible for hollowing out the present basin of Lake Ontario, the bottom of which lies 500 feet below sea level. The Genesee River at this period flowed northward until it reached the Salina depression, where it turned eastward a few miles and then north, cutting through the Niagara limestones to form the Irondequoit valley.

With the advent of the Pleistocene glacial ice sheet, covering Lake Ontario and northern New York, all drainage was forced to the south, and after the recession of the glacier, the Genesee River resumed its northward course and now remains the sole survivor of the old northerly flowing pre-glacial rivers. Morainic dams changed its course somewhat and instead of flowing eastward in the Salina depression, it was forced to run directly north and cut another gorge through the limestones, forming the present Rochester canyon. This left a small stream to flow through Irondequoit Valley. As the ice receded and uncovered the western part of the Ontario basin, Glacial Lake Dawson was formed, extending as far west as Irondequoit Bay and including it as its

western end. Subsequently, the bay formed a part of Glacial Lake Iroquois, which extended over a much wider area. Lake Ontario and Irondequoit Bay, particularly its lakeward extension, are now partially filled with glacial deposits to an unknown depth. Late in its history, a bar was thrown across the mouth of the bay leaving only the narrow, shallow outlet into Lake Ontario.

To the south of this bar is a wide, marshy area, through which the outlet runs a tortuous course, with the flow of water running from the bay into the lake. For all practical purposes, therefore, Irondequoit Bay may be considered a separate body of water and in its actions behaves exactly like an inland lake. The main axis of the lake lies in a north-south direction with the length approximately eight times the average width. The hydrographical data given in table 1 are from a map made by the Rochester City Planning Board.

TABLE 1.—Morphological and hydrographical data on Irondequoit Bay.

| | |
|---------------|-------------------------|
| Length | 6 kilometers |
| Average width | 0.8 kilometers |
| Area | 650 hectares |
| Volume | 57,500,000 cubic meters |
| Mean depth | 6.3 meters |
| Maximum depth | 23 meters |

The shores along the north central part of the bay are very steep and reach a height of upwards of 100 feet; this is particularly true in the region near the deepest portion, between Stony Point and Point Pleasant. At the northern end and to the south, the banks level to low, marshy shores, while the southern third of the bay is almost completely filled with emergent aquatic plants (fig. 1).

The water of Irondequoit Bay is derived from Irondequoit Creek, which enters through the swampy area at the southern end, and from several smaller streams along the eastern and western shores. Water from Lake Ontario never mixes with the bay water except possibly during the most severe winter storms, a fact clearly shown by the wide difference in specific conductivity of the two bodies of water. Most of the incoming water is evidently lost through evaporation, although there is a slight flow of water through the outlet into Lake Ontario. The waters of Irondequoit Creek carry sewage from several small towns along its banks and this is also true, to a much lesser degree, of some of the other tributaries. The pollution situation will be discussed further on in this paper.

METHODS

Regular monthly series of samples were taken in the deep water area between Point Pleasant and Stony Point where the water was 20 meters or more in depth over a considerable area. Samples were secured at eight intermediate depths, except during the winter months when conditions were comparatively uniform and five depths were sampled. A limited amount of sampling was also done at irregular intervals at the outlet and in Irondequoit Creek.

Temperature was determined by a Negretti-Zambra deep-sea reversing

thermometer; transparency of the water by the Secchi disc and specific conductivity by the Digby and Biggs Dionic Water Tester. Chemical procedures were those outlined by Birge and Juday (1911) or by the American Public Health Association (1936). Quantitative determinations of centrifuged (par-

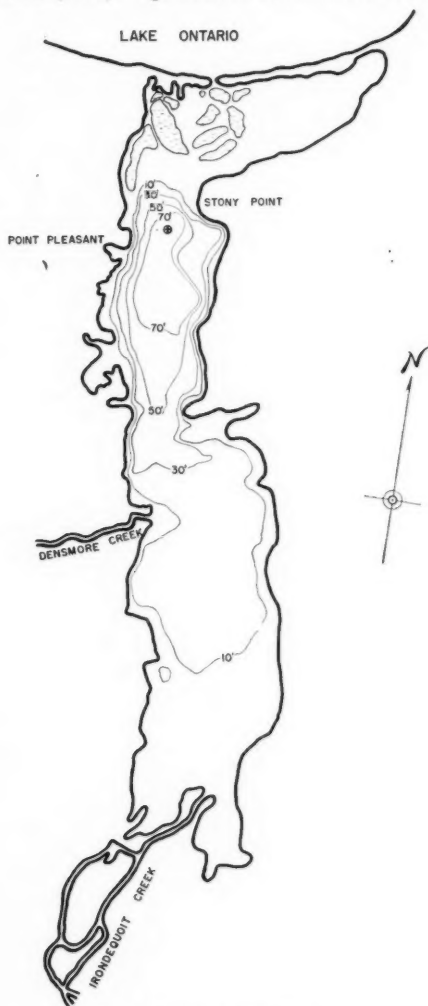


Fig. 1.—Map of Irondequoit Bay

ticulate) organic matter were made at each depth sampled throughout the year. A liter of water was centrifuged in a Juday-Foerst centrifuge and the organic matter determined by loss on ignition. Macroplankton was secured with a 10 liter Juday-Foerst plankton trap; microplankton was obtained from a 500 cc. sample collected with a Kemmerer-Foerst water bottle and centrifuged in the Juday-Foerst centrifuge. Counts were made to genera; macroplankton counts were determined by counting all the organisms (Crustacea and Rotifera) in each of two 1 cc., samples, while microplankton was determined by the random count method, twenty squares being counted in a Sedgwick-Rafter cell under 200 diameters magnification.

TEMPERATURE

Figure 2 shows the seasonal variation in temperatures at the surface, at 10 meters, and at the bottom. Figure 4 shows the vertical distribution of temperature at six periods during the year. Irondequoit Bay may be considered to be a cold water lake since the maximum summer bottom temperature was 7.5°C . Stratification was present from May to October with a distinct and pronounced thermocline present during the summer. In August the thermocline was located between 8 and 10 meters, in September it had dropped to the region between 10 and 15 meters, and in October the entire body of water was of uniform temperature ($11.7\text{--}12.8^{\circ}\text{C}$.). During the winter the usual slight stratification common to most lakes of this type occurred, and persisted until early May when a thermocline again made its appearance at between 5 and 8 meters. In June this had extended down to 10 meters. While Irondequoit Bay shows the usual progression of the thermocline, it is in direct contrast to the conditions found in Chautauqua Lake. In Chautauqua the thermocline became narrower in vertical extent and moved upward as the summer progressed, thorough mixing occurring at the rather high temperature of 17°C ., in mid-September. This unusual condition was due to the broad, shallow area of water and to the unprotected expanse over which the wind had free play during the entire summer. Irondequoit Bay, on the other hand, is extremely well protected from wind action by its high, steep banks and narrow width, so that vertical mixing depended mainly upon density currents and was aided little by the wind.

Bottom water remained cold except at the time of the fall turnover when it rose to 11.7°C ., or within one degree of the temperature of the surface water at that time. The minimum bottom temperature observed occurred on January 27, 1940 (2.6°C .). The lowest water temperature recorded was 0.8°C ., at the surface on March 21, 1940. Ice coverage was 115 days, from December 28, 1939 to April 11, 1940. Ice reached a maximum thickness of about 30 cm., with 20 cm. of old icy snow and 8 cm. of new snow on top on March 21, 1940.

An annual heat budget, based upon temperatures taken January 27, 1940, was computed as 8,350 gram calories per unit area; wind distributed heat on August 15, 1939 was 6,740 gram calories. Chautauqua Lake gave an annual heat budget of 13,420 gram calories in 1937.

TRANSPARENCY

The water of Irondequoit Bay is of comparatively low transparency as measured by the Secchi disc. The maximum transparency was recorded in June 1940 (5.8 meters) and the minimum on September 24, 1939 (1.3 meters). The average transparency reading during the year was 2.7 meters. These figures compare very favorably with those obtained in Chautauqua Lake, where the average throughout the year was 2.8 meters with a maximum of 5 and a minimum of 2 meters. In Chautauqua Lake, however, a direct correlation existed between transparency and particulate organic matter, while in Irondequoit Bay this was true only in a general way. The maximum transparency was obtained in June when the mean organic matter was at a minimum but at most other times transparency did not follow organic matter very closely or showed little or no correlation with it. No correlation existed between quantitative plankton and transparency. In Irondequoit Bay we must turn to other factors for an explanation of the seasonal changes in transparency and perhaps the most important of these involve allochthonous detritus and material from the erosion of the steep banks of the lake. This supposition is borne out by the low transparency which occurred during April and May. Between March and April a marked drop in transparency occurred which was not correlated with an increase in organic matter but which was evidently due to material washed in during the spring rains. In May, after the spring overturn, a very great increase in organic matter was correlated with a continuance of low transparency. Color can be dismissed as a factor modifying transparency as the waters of Irondequoit Bay showed only the slightest trace of color.

SPECIFIC CONDUCTANCE

Beginning with the October 1939 series of samples, the specific conductance of Irondequoit water was measured at all intermediate depths sampled. These readings were automatically corrected for temperature at the time they were made and all results are expressed as the conductivity in reciprocal megohms at 20° C. Specific conductance is the reciprocal of the resistance offered to the passage of an electrical current through one cubic centimeter of water; one unit of conductivity being the reciprocal of the resistance of one million ohms, or one megohm. While the field instrument used is not as accurate as the standard laboratory apparatus for measuring specific conductance, comparisons with it have shown that the limit of error is never greater than 5 per cent and is usually between 0 and 3%.

Juday and Birge (1933) reported on an examination of 530 lakes in Northeastern Wisconsin in which the conductivity ranged between 3 and 132 units. These bodies of water were located in a glacial region and many of them were seepage lakes possessing neither inlet nor outlet. In the southern part of Wisconsin, conductivities average considerably higher due to the prevalence of limestone in that region; the lakes in and near Madison run between 200 and 300 units of specific conductance. Welch (1936) reports that the known range of conductivity for Michigan lakes is between 10 and 330 units.

In New York, only a few lakes in the western half of the state have been

tested for specific conductance. The results are given in table 2. The conductivity of Irondequoit Bay is given as 500 units on May 16, 1940, so that the conductivity of two other lakes to the west may be compared with it. Actually the conductivity of Irondequoit Bay was somewhat higher than 500 at other times of the year, the surface readings over the nine-month period averaging 563 units.

TABLE 2.—The conductivity of some lakes of western New York. The results are expressed in terms of reciprocal megohms resistance at 20° C. All determinations are from surface samples.

| Lake | County | Date | Conductivity |
|------------------|-------------|---------------|--------------|
| Canadice | Ontario | May 12, 1940 | 85 |
| Chautauqua | Chautauqua | Dec 30, 1939 | 116 |
| Honeyoye | Ontario | May 12, 1940 | 125 |
| Hemlock | Livingstone | May 12, 1940 | 135 |
| Conesus | Livingstone | May 12, 1940 | 230 |
| Canandaigua | Ontario | May 12, 1940 | 230 |
| Mendon | Monroe | Jun. 13, 1940 | 245 |
| Seneca | Seneca | May 10, 1940 | 250 |
| Keuka | Steuben | May 10, 1940 | 250 |
| Erie Barge Canal | Orleans | Apr 21, 1940 | 330 |
| Genesee River | Monroe | Dec 20, 1939 | 370 |
| Como | Erie | Nov 19, 1939 | 393 |
| Ontario | Monroe | Nov 26, 1939 | 430 |
| Horseshoe | Genesee | Dec 20, 1939 | 460 |
| Irondequoit | Monroe | May 16, 1940 | 500 |
| Glenwood | Orleans | May 16, 1940 | 500 |
| Carlton | Orleans | May 16, 1940 | 550 |
| Park | Erie | Nov 19, 1939 | 1300 |

Seasonal variation of the surface water of Lower Lunz lake in Europe was reported by Ruttner (1914). The highest readings were obtained in autumn and winter and the lowest in May. The lakes of Northeastern Wisconsin have not been followed throughout the year. In Lake Wingra, a small lake at the outskirts of Madison, Wisconsin, conductivity showed a steady increase from January on (292-394 units) (Tressler and Domogalla, 1931). In Irondequoit Bay, mean specific conductivity (the average of all depths sampled) showed a steady rise from October until March, varying between 564 and 676 units. In April it had dropped to 556 and in May to 524; the June sample showed a conductivity of 556. The increase during the winter is correlated with a steady rise in methyl orange alkalinity (fig. 2). The maximum mean methyl orange alkalinity occurred in February, after which there was a decline until June, when a slight upward trend had started.

In their studies of the various lake groups of Northeastern Wisconsin, Birge and Juday found a decided correlation between fixed carbon dioxide and conductivity. In most cases this correlation was also evident in the vertical distribution of these factors. In some lakes, the conductivity readings were substantially the same from surface to bottom, while others showed differences of from 1 to 6 units within this range. Trout Lake showed a maximum difference in conductivity between surface and bottom of only 5 units. In Wild

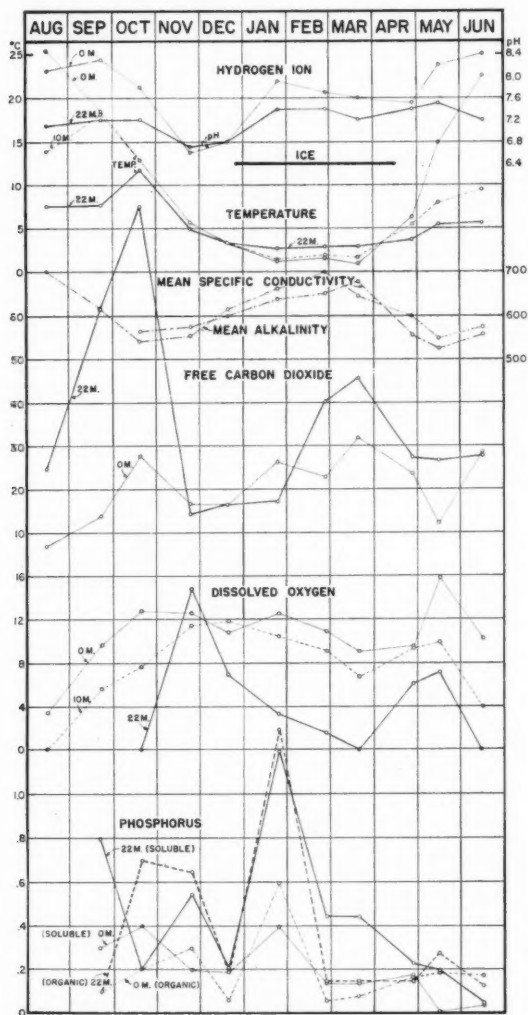


Fig. 2—Seasonal variation of physical and chemical factors

Cat Lake, however, a maximum difference of 51 units was observed in August (128-179 units respectively). Lakes which showed slight differences in conductivity between surface and bottom, showed only slight increases in fixed carbon dioxide at the bottom, while Wild Cat Lake ranged from 30.8 mg/l at the surface to 44.1 mg/l at the bottom of fixed carbon dioxide.

Irondequoit Bay always had a higher specific conductance in the bottom waters and this increase was also correlated with a decided increase in fixed carbon dioxide. In October, December, and June, the increase in conductivity amounted to 20 units, in April, 30 units, November and May, 40 units, while the maximum difference occurred during the winter stagnation period in January, February, and March, when the difference in conductivity between surface and bottom was 130, 230, and 210 units respectively. In February the surface waters gave a conductivity of 580 units and the bottom water 800. Methyl orange alkalinity on this date varied from 124.5 p.p.m. at the surface to 161.5 p.p.m. one meter above the bottom. At ten meters depth the alkalinity was 176 p.p.m., but a correspondingly great increase in conductivity was not noted at this depth. In March, conductivity ranged from 600 to 810 units from surface to bottom and alkalinity from 115 to 192 p.p.m. Measurement of specific conductance was not made during the summer stagnation period in 1939 due to lack of instruments, but it is to be expected that a similar marked increase from surface to bottom would have been correlated with the increase in alkalinity (83-192 p.p.m.).

Juday and Birge (1933) found in some lakes that the conductivity was higher at the surface than at 3-5 meters. This difference never was greater than 1 unit. Ruttner (1914) found similar and somewhat greater differences at these depths. Measurements of conductivity were not taken at 3 meters in Irondequoit Bay but at 5 meters, no decrease was found in nine series taken from October to June. Differences of less than 5 units could not be measured on the scale of the Dionic Water tester which was used on Irondequoit Bay when conductivities were as high as 500 units. In all series of samples taken, specific conductance showed a regular increase between surface and bottom. In the series taken in January, February, April, May, and June, conductivity was the same at the surface as at 5 meters, while in all the other series there was a slight increase at 5 meters.

On April 21, 1940 at a time when a severe north wind was blowing directly into the outlet, a series of samples was taken to determine to what extent Ontario water was mixing with Irondequoit Bay water. At this time the water off the Point Pleasant dock had a conductivity of 560 units, while in November, Lake Ontario had a conductivity of only 430 (Irondequoit Bay water at that date was 590 units off the Point Pleasant dock). A sample taken on April 21, right at the mouth of the outlet gave a specific conductance of 540 units, another taken about 100 feet south, where the lake shore highway crosses the outlet, gave a conductance of 550, while about 75 feet further up the outlet at Rebholz's dock, the conductivity was the same as at Point Pleasant (560). These determinations show conclusively that there is no mixing of the waters of Lake Ontario with those of the Bay even during such strong gales from the north as were experienced on April 21, 1940. On

this same day, the conductivity at the inlet where highway 104 crosses Irondequoit Creek, was only 575, further up at Blossom Road it was 560, at Baird Road and Thomas Creek, 590, at highway 33B, 500 and at highway 31, 565. The Barge Canal, which crosses over Irondequoit Creek, gave a conductivity of 330 on April 21.

CHEMISTRY

Free carbon dioxide.—Seasonal distribution of free carbon dioxide at the surface and at the bottom is shown in fig. 2. A superabundance of this gas was present at all depths during the entire year. Surface and bottom water showed maxima in October and March. The maximum amount of free carbon dioxide at the surface occurred on March 21, 1940 (32 p.p.m.) and the minimum on August 15, 1939 (7 p.p.m.); the minimum amount at the surface occurred at a time of maximum phytoplankton activity. A maximum of 83 p.p.m. at the bottom was observed on October 22, 1939, while in March 1940 the maximum was 45 p.p.m. Minimum amounts at the bottom were observed during November, December, and January at which times free carbon dioxide was distributed almost equally from surface to bottom. The large amounts of this gas generated by high bottom decomposition during the summer were dissipated following the fall overturn by escape to the atmosphere previous to the formation of the ice cover in late December. Following the closing of the lake, accumulations again began to build up under the ice with marked stratification from surface to bottom. On March 21, the surface water showed 32 p.p.m., and the bottom water 45 p.p.m. of free carbon dioxide. The vertical distribution at other times during the year is shown in fig. 4. The rapid and truly enormous accumulation of carbon dioxide in the bottom waters of Irondequoit Bay may be ascribed to the interaction of three factors: (1) the inflow of a small but steady amount of polluted water principally by way of Irondequoit Creek, (2) the high rate of decomposition of the bottom materials and (3) the almost complete lack of circulation of the water of the bay with Lake Ontario water. Little can be done to remedy the first two conditions since the degree of pollution is apparently not severe enough in Irondequoit Creek to warrant complaint. On the other hand this slight amount of polluted water does serve to fertilize the bay water and increases plankton production. Lack of circulation with the waters of Lake Ontario could be remedied by the cutting of a fairly deep channel from the lake as far as the deeper water just north of Point Pleasant. Since there is little natural flow from the bay into the lake, this channel would have to be kept open by periodical dredging, although there might be enough inwash from the lake to reduce such dredging to a minimum. This plan of opening the bay has been proposed by local people at several times for many years and it is our opinion that such an opening would greatly reduce stagnation conditions and might very well improve fishing conditions in the bay. From the standpoint of the limnologist, a channel would probably ruin Irondequoit Bay as an extreme example of summer and winter stagnation. Conditions during the mid-summer and mid-winter periods are truly extremely exaggerated examples of the most severe stagnation usually found in ordinary inland bodies of water, a fact which will be even more appreciated in the discussion of dissolved oxygen,

which follows, and in the other chemical conditions in the bay. Recently one or two examples of extreme stagnation conditions in American lakes have been reported, including one lake in the west which appears to be permanently stratified and which approaches the conditions found in some lakes in the Philippines and East Indies where the life zone is restricted to the upper few meters only (Woltereck, Tressler and Buñag, 1941).

Dissolved oxygen.—Dissolved oxygen at the surface, 10 meters, and at the bottom is shown throughout the year in fig. 2. Vertical distribution of oxygen at six periods throughout the year is shown in fig. 4. In general, the maximum amounts of oxygen at the surface were observed during the fall and winter months; the absolute maximum occurred in May (15.9 p.p.m. or 156% saturated). The minimum amount at the surface was in mid-August (3.4 p.p.m. or 40% saturated).

During August no oxygen existed below 10 meters depth and on September 24, none was present at 15 meters and only 5 p.p.m. at 10 meters. On October 22, mixing of the water had progressed almost to the bottom and there were 6 p.p.m. of oxygen at 15 meters but none at 20 meters. Complete overturn and restoration of oxygen took place between October 22 and November 26, when oxygen was very abundant at all depths. By mid-December, one week before the ice formed, a slight decrease in oxygen below 15 meters was noticeable and on January 27, only 3.4 p.p.m. (25% saturated) was present at 20 meters. This amount had been further reduced to 1.6 p.p.m. (11% saturated) on February 28, and on March 21, none existed at 20 meters. At this later date the water at 10 meters was only 50% saturated. The spring overturn in April restored oxygen to all depths. This condition only persisted through May, and by June 13, no oxygen was found at 20 meters and only 5 p.p.m. at 15 meters. These conditions of extreme stagnation are caused by the same factors that were mentioned in the discussion of carbon dioxide. Irondequoit Bay, from the standpoint of oxygen depletion in the hypolimnion, is an extremely eutrophic type of lake.

Hydrogen ion concentration.—Figure 2 shows pH at the surface and bottom throughout the year. Vertical distribution of pH is shown in fig. 4. Throughout most of the year the water of both epilimnion and hypolimnion remained alkaline, but in November and December 1939, for some unknown reason, the water from surface to bottom became acid with a pH of between 6.6 and 6.8. In January, the water showed a pH range of from 7.9 at the surface to 7.4 at 20 meters. No satisfactory reason has been found to explain this sudden change to acid conditions; dilution by rains, inwash from the shores, in fact nothing short of actual influx of water of low pH seems to account for it. At all other times during the year, the water showed normal pH readings with alkaline water in the upper portion, which became less alkaline and sometimes almost neutral at the bottom.

Alkalinity.—The seasonal distribution of mean alkalinity is shown in connection with mean specific conductance in fig. 2. Mean alkalinity was highest in mid-summer (150 p.p.m.) and again in February (149 p.p.m.). Low points were reached in early fall (110 p.p.m. in October) and in May (111 p.p.m.). From October, a general rise to the maximum in February followed

very closely a similar rise in mean conductivity. The greatest mean conductivity was observed in March, following which a regular drop occurred until May; the June samples showed a slight rise. The mean alkalinity followed very closely, so that in Irondequoit Bay, alkalinity and conductivity are correlated with each other. The literature does not seem to show a similar study of these two factors throughout the year, although the studies of Birge and Juday (1933) already mentioned, did indicate a close correlation during part of the season.

Vertical distribution of alkalinity is shown in fig. 4. Very marked increases in alkalinity toward the bottom were observed at several times during the year. On August 15, 1939, there was a difference of 108 p.p.m. between surface and bottom; on March 21, 1940 a difference of 77 p.p.m. was observed. The March increase in the bottom water was correlated with an increase in conductivity of 210 units. In November and in June, alkalinity was slightly higher at the surface than at the bottom. These great differences in alkalinity between surface and bottom may perhaps be explained by the inflow of polluted water from Irondequoit Creek, which flows along the bottom and becomes trapped in the deeper parts of the lake, during the stagnation periods. The great amount of decomposition on the bottom is also undoubtedly another factor in the unusual increase in alkalinity near the bottom.

Phosphorus.—Determinations of soluble and total phosphorus were made from September to June. The difference between soluble and total phosphorus is reported as organic phosphorus. Seasonal distribution of soluble and organic phosphorus at the surface and bottom is shown in fig. 2. The role played by phosphorus as a limiting factor in phytoplankton production has always been of doubtful significance. Atkins (1923, 1925, 1926) and Atkins and Harris (1924) found a direct correlation between phosphorus and plankton growth, phosphorus being a limiting factor. Juday, Birge, Kemmerer, and Robinson (1927) on the other hand found no correlation between soluble phosphorus and phytoplankton nor between organic phosphorus and centrifuge plankton. Juday and Birge (1931) reported that phosphorus seemed to be a limiting factor in some lakes with minimal phosphorus values. Wiebe (1931) found that when phytoplankton was high, low phosphorus was observed, thus indicating phosphorus as a limiting factor. In Chautauqua Lake, phosphorus did not show a clear correlation with plankton growth (Tressler, Wagner, and Bere, 1940).

In Linsey Pond, Riley (1940) found a significant correlation between the nitrate and phosphate content of the surface water and phytoplankton and concluded that phosphate was the more important limiting factor. Some experimental work by Hutchinson and Riley (Hutchinson, 1941) suggested that although nitrate was somewhat more significant than phosphate in producing an increase in phytoplankton growth, both elements must be present before any other possible limitation can come into play. The importance of iron in limnetic phosphorus metabolism has been pointed out by Einsele (1936, 1938), Hutchinson (1941) and Deevey (1940). Deevey suggests that the high plankton productivity of Connecticut lowland lakes is due not to an absolute richness in phosphorus but to a geologically determined set of characters including iron.

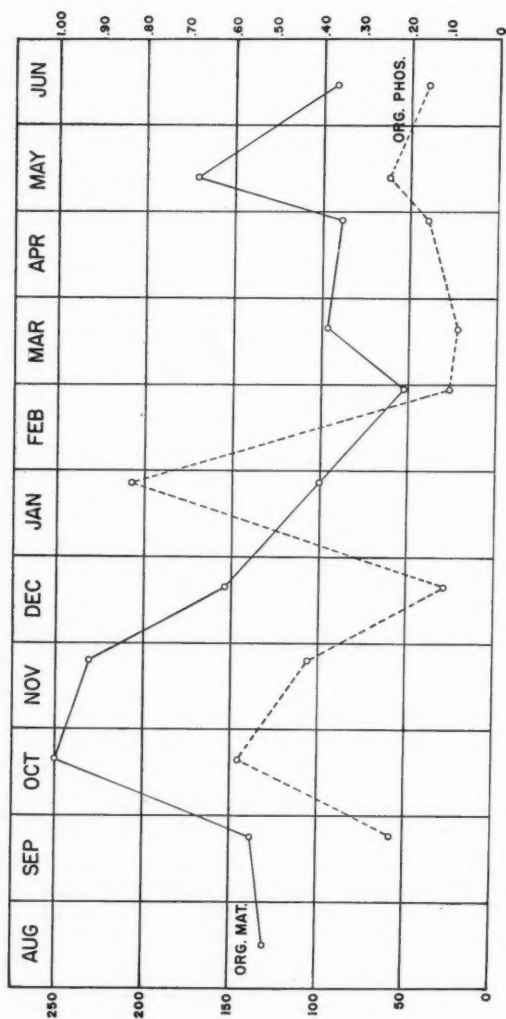


Fig. 3.—Seasonal distribution of mean organic matter and mean organic phosphorus

If one compares the curves for phosphorus (fig. 2) with both the mean organic matter in the centrifuge plankton and the seasonal distribution of the various genera of phytoplankton (fig. 5), there appears to be little correlation between mean organic matter and organic phosphorus, and also little between soluble phosphorus and phytoplankton. When mean organic matter is plotted with mean organic phosphorus (fig. 3), it is found that the curves follow each other exactly with one exception (January), which may be an error in determination. There is, therefore, a direct correlation between organic matter and organic phosphorus in Irondequoit Bay, both rising and falling together as would be expected but which it has not been possible to show in many cases heretofore. Mean soluble phosphorus does not show as clear cut a correlation with the total phytoplankton crop. In October and following the fall maximum in diatoms, there is a gradual drop to a minimum in December, and again in February (if we exclude the January sample, which is abnormally high). In May, at the time of the spring diatom maximum, soluble phosphorus showed a marked drop and then a rise in June. In the fall, mean soluble phosphorus was considerably less than organic phosphorus. In December, there was less organic phosphorus than soluble and this condition (except for the January series) continued until May; in June there was again more soluble phosphorus than organic phosphorus.

The vertical distribution of organic phosphorus showed some increase in the bottom waters at most times. Exceptions to this occurred in April when there was 0.17 p.p.m. at the surface and 0.150 p.p.m. at the bottom, and in June when organic phosphorus was 0.18 p.p.m. and 0.13 p.p.m. at the surface and bottom respectively. The November and May series showed a regular increase in organic phosphorus from surface to bottom. The October series had maxima at 10 meters and at the bottom, while from December through April, there was less organic phosphorus at 5 meters than at the surface. There was always more soluble phosphorus at the bottom than at the surface. In February, March and May, soluble phosphorus increased regularly from surface to bottom; at other times the distribution was rather irregular. During October, January, and April, there was less soluble phosphorus at 5 meters than at the surface, but in every other monthly series the reverse was true.

Juday and Birge (1931) in a study of 479 lakes of Northeastern Wisconsin, found soluble phosphorus at the surface to range between 0 and 0.015 p.p.m., while organic phosphorus ranged from 0.005 to 0.103 p.p.m. Due to pollution coming in by way of Irondequoit Creek, phosphorus exceeded these amounts considerably. At the surface, soluble phosphorus ranged from 0.01 to 0.4 p.p.m., with a maximum of 1.1 p.p.m., at the bottom on October 24, 1939. Organic phosphorus ranged at the surface from 0.03 p.p.m., to 0.6 p.p.m., with a maximum of 3.5 p.p.m. at the bottom on October 24, 1939.

Unfortunately no determinations of nitrogen values were made, so that nitrogen-phosphorus relationships in Irondequoit Bay can not be determined.

POLLUTION

The extremely high phosphorus values are indicative of pollution and while the extensive program of pollution investigation had to be curtailed,

enough was completed to show that Irondequoit Creek is an important source of polluted water. On November 26, 1939, the conductivity of the surface water off Point Pleasant was 590 units (bottom water conductivity was also 590 units) while Irondequoit Creek just before entering the swampy area at the south end of the bay (where highway 104 crosses the creek) had a conductivity of 750. On December 20, 1939, the surface water of Irondequoit Bay showed a conductivity of 590 (bottom water was 610) and Irondequoit Creek at highway 104 was 650. Going upstream from this point, samples were taken where highways crossed the creek with results as follows: at highway 35A the conductivity was 850; at highway 35, 850; at highway 33, 900; highway 253, 875; highway 33A, 850. The Genesee River only a few miles to the west of Irondequoit Creek at highway 35, above the city of Rochester, had a conductivity on this date of only 370. For this reason it is believed that pollution and not terrain accounted for the high conductivities in Irondequoit Creek. The source of pollution was not investigated, but it is well known that a number of sewers empty into the creek from neighboring small towns. On April 21, 1940, the surface water in Irondequoit Bay was 560 off Point

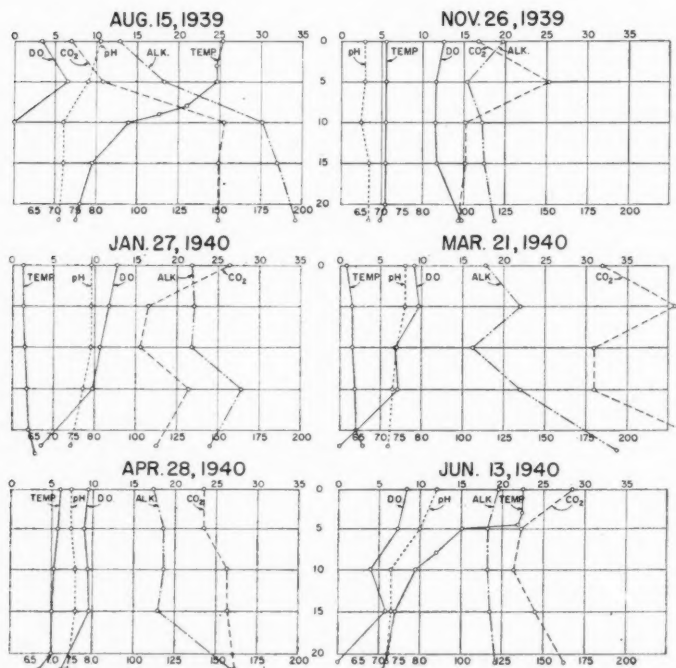


Fig. 4.—Vertical distribution of physical and chemical factors at six periods of the year

Pleasant, while the following values were observed in Irondequoit Creek: at highway 104, 575; Blossom Road, 560; highway 33B, 500 and highway 31, 565. A week later on April 28, 1940, with the bay water showing a conductivity of 550 at the surface, Irondequoit Creek, one mile above highway 31, had a conductivity of 730, but near its source, above the town of Meridon, the conductivity was only 370, which compares very well with the value obtained in the unpolluted area of the Genesee River on December 20.

Were it not for the very high phosphorus values, the nature of the terrain might explain the high conductivities obtained in Irondequoit Creek and the somewhat lower results obtained in the bay itself, since the region is a limestone area and such lakes as Carlton and Glenwood have conductivities of about the same order of magnitude as Irondequoit Bay.

Pollution in Irondequoit Bay is not believed to be serious enough to do more than increase the growth of plankton and certainly can not account for the decline in fishing which has been so much publicized during the past few years.

ZOOPLANKTON

Ten liters of water were collected with a Juday-Foerster plankton trap and were reduced to 20 cc., and preserved in formalin. Two 1 cc. samples were removed with a Stempel pipette and all the organisms counted in each sample. Results were expressed as the number of organisms per cubic meter.

The species identified are given in the list below, but as these represent only the limnetic forms, no attempt having been made at sampling the littoral or marshy areas of the lake, the list is far from complete and no conclusions can be drawn as to the variety of plankton forms supported by the bay as a whole. The limnetic forms collected at the Point Pleasant station show an average variety when compared with other lakes.

COPEPODA

Cyclops bicuspidatus (Claus)

Diaptomus siciloides (Lilljeborg)

Cyclops leukarti (Claus)

CLADOCERA

Alona sp.

Daphnia pulex (de Geer)

Bosmina longirostris (Müller)

Daphnia retrocurva Forbes

Daphnia longispina (Müller) var. *hyalina*
(Leydig) form *galeata*

Leptodora kindtii (Focke)

Sida crystallina (Müller)

ROTIFERA

Asplanchna priodonta Gosse

Notholca longispina Kellicott

Asplanchna sp.

Polyarthra trigla Ehrenberg

Keratella cochlearis (Gosse)

Rattulus sp.

Keratella quadrata (Müller) var. *divergens*

Synchaeta stylata Wierzejski

Monostyla bulla Gosse

The seasonal distribution of the more important genera is shown in fig. 5, where the mean of samples at all depths is shown. The vertical distribution of the groups as a whole is shown in fig. 6.

Copepoda.—Two genera of copepods were found in Irondequoit Bay. Of these, *Cyclops* represented by two species, was the more abundant and was found in the plankton counts throughout the entire year. The greatest num-

ber (594,000 per cubic meter) was observed at the surface on May 16, 1940. The second highest concentration of *Cyclops* occurred on September 24, 1939 when 90,000 per cubic meter were found at 15 meters. Minimum numbers of *Cyclops* were found in December and April when the average numbers of individuals in the five depths sampled were 16,000 and 20,000 per cubic meter, respectively.

Diaptomus siciloides.—The only representative of this genus present in the limnetic region of the bay was also found in all counts at all times during the year, although it became very scarce during April 1940. This species was abundant in the fall until late December, appearing in maximum numbers at 15 meters on September 24, 1939 and at the surface on December 20 (44,000 and 40,000 per cubic meter respectively). From January on its numbers became less until June when the same average number present during the preceding August was observed. The seasonal distribution of *Diaptomus siciloides* is explained by the fact, long ago pointed out by Birge (1897) that *Diaptomus* makes no provision for winter forms. The numbers of individuals gradually are thinned out by predators or they die of old age, leaving only enough for brood stock in the spring after the water has warmed up. Nauplii were found during the whole year but showed a considerable decrease in numbers during January, February, and March. The maximum number was observed on May 16, 1940 at the surface (604,000 per cubic meter). During January, February, and March, the average number of nauplii at the various depths sampled was 7,000 per cubic meter. The greatest numbers of nauplii occurred in the epilimnion during summer and spring, in the hypolimnion in September and at other times their vertical distribution was comparatively even from surface to bottom.

Cladocera.—Five genera of cladocerans were found in the bay but only one of these, *Daphnia*, appeared in any abundance. *Daphnia* was represented by three species and was present during the entire year. Its abundance increased during the fall to a maximum in September and in December and January, after which the numbers fell off until May when they were again abundant. During the September maximum, there were 87,000 *Daphnia* per cubic meter at 5 and 12 meters. *Bosmina longirostris* was found in small numbers during most of the year except during February and March, when it was not seen in the counts. It was at a maximum in August (2,000 per cubic meter at 5 meters). *Sida crystallina* was fairly abundant during August, September, and October but was never seen again in the counts. It was present in numbers of 5,000 per cubic meter at 5 meters depth on August 15, 1939. *Leptodora kindtii* appeared once in the counts in September. This form is large and powerful enough to see and swim out of the trap or away from vertical haul nets and that accounts for the infrequency with which it appears in plankton counts. In Buckeye Lake, Ohio this large form was never observed in tows or in trap samples but a tow with a meter net yielded 2 liters of almost pure *Leptodora* (Tressler, Tiffany and Spencer, 1940).

Rotifera.—Eleven genera of rotifers were found in Irondequoit Bay, four of which were abundant during the greater part of the year. *Keratella cochlearis* was present during the year with greatest numbers in the fall. On Octo-

ber 22, 1939, the maximum number of 158,000 per cubic meter was observed at 10 meters. From November on the numbers decreased and reached a low level during April. *Asplanchna* showed approximately the same seasonal distribution as *Keratella* but had its maximum in May (131,000 per cubic meter at the surface). *Polyarthra* had maxima in September (32,000 per cubic meter at 3 meters) and in May (61,000 per cubic meter at the surface). *Notholca longispina* was seen in the counts from September through April, reaching a maximum of 52,000 per cubic meter at 23 meters in October. The other rotifers were observed mainly in the fall of the year in small numbers.

In Chautauqua Lake, *Keratella cochlearis* showed two maxima, one in October and the other in May (in May, 294,000 per cubic meter at 8 meters was observed). *Asplanchna* was fairly abundant during the winter months, while *Brachionus* and *Conochilus*, two rotifers not observed in Irondequoit Bay, appeared in the counts. *Conochilus* showed maximum numbers in May (50,000 per cubic meter at 3 meters).

The vertical distribution of rotifers in Irondequoit Bay showed greater numbers in the epilimnion during the summer and early spring and fairly even distribution at other times of the year. In Chautauqua Lake, the rotifers were fairly evenly distributed from surface to bottom with somewhat greater numbers at intermediate depths on most occasions.

PHYTOPLANKTON

Phytoplankton was determined by running a 500 cc. sample, collected with a Kemmerer-Foerst water bottle, through a Juday-Foerst centrifuge. The centrifuged sample was preserved in formalin and made up to 10 cc. After thorough shaking and mixing, a sample was withdrawn with a pipette and placed in a Sedgwick-Rafter counting cell 1 mm. deep. Twenty random counts were made at 200 power magnification. Results were computed as the number of organisms per liter. Approximately the same standards of units and lengths were used in counting as was followed by Tiffany in the Buckeye Lake work (Tressler, Tiffany, and Spencer, 1940). Thus, *Scenedesmus* colonies of 4 cells were counted as a unit, as was the case with other definite colonies such as *Oocystis*. In the case of the filamentous forms, 300 micra was selected as the length of one unit, while 5 cells were taken as a unit of *Dinobryon*, *Merismopedia* 16 cells, and *Crucigenia* 8 cells.

The following is a list of the phytoplankton as far as the identity of species could be determined. Counts were made only to genus.

CHLOROPHYCEAE

Ankistrodesmus falcatus (Corda) Ralfs
Characium limneticum Lemm.
C. cylindricum Lambert
Chlamydomonas sp.
Chlorococcum infusionum (Schrank)
 Meneghini
Closteriopsis longissima var. *tropica*
 W. & G. S. West
Coelastrum microporum Nägeli
Crucigenia tetrapedia (Kirchner)
 W. & G. S. West

Cosmarium sp.
Dictyosphaerium pulchellum Wood
Elaktothrix gelatinosa Wille
Gloeocystis gigas (Kütz.) Lagerh.
Lagerheimia subsalsae Lemm.
Mougeotia sp.
Oocystis borgei Snow
O. crassa Wittrock
O. parva W. & G. S. West
Nephrocystium limneticum G. M. Smith
Pediastrum boryanum (Turpin) Meneghini

P. duplex Meyen
P. simplex var. *duodenarium* (Bailey)
 Rabenhorst
Quadrigula pfizleri (Schröder) Lemm.
Scenedesmus abundans (Kirchner) Chodat
S. arcuatus var. *platydesca* (Lemm.)
 G. M. Smith
S. bijuga (Turpin) Lagerh.

S. quadricauda var. *maximus*
 W. & G. S. West
S. dimorphus (Turpin) Lagerh.
Schroederia setigera (Schröder) Lemm.
Selenastrum minutum (Nägeli) Collins
Sphaerocystis schroeteri Chodat
Staurastrum sp.

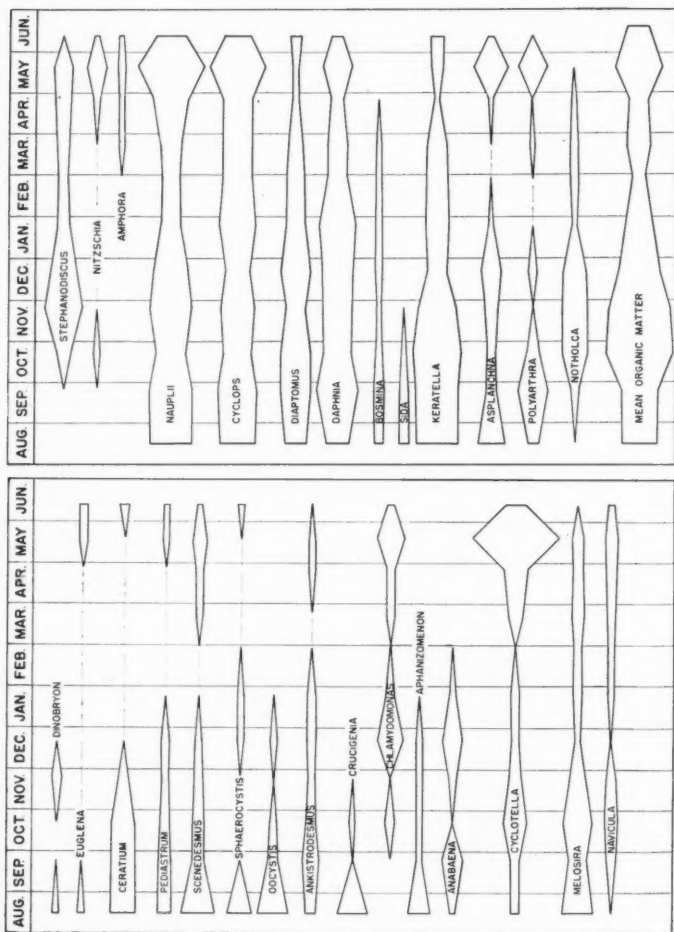


Fig. 5.—Seasonal distribution of the more abundant genera of plankton organisms

MYXOPHYCEAE

- | | |
|--|---|
| <i>Anabaena flos-aquae</i> Born & Flah. | <i>C. dispersus</i> (V. Keissler) Lemm. |
| <i>A. planctonica</i> Brunthaler | <i>C. minutus</i> (Kütz.) Nägeli |
| <i>A. spiroides</i> var. <i>crassa</i> Lemm. | <i>Merismopedia punctata</i> Meyen |
| <i>Aphanothece</i> sp. | <i>M. tenuissima</i> Lemm. |
| <i>Aphanizomenon flos-aquae</i> Born & Flah. | <i>Oscillatoria</i> sp. |
| <i>Chroococcus limneticus</i> Lemm. | |

DIATOMEAE

- | | |
|--|--|
| <i>Amphora</i> sp. | <i>Gyrosigma</i> sp. |
| <i>Asterionella formosa</i> Hass | <i>Melosira crenulata</i> (Ehrenb.) Kütz. |
| <i>Cocconeis</i> sp. | <i>Meridion</i> sp. |
| <i>Cyclotella comta</i> (Ehrenb.) Kütz. | <i>Navicula</i> sp. |
| <i>C. striata</i> Grun. | <i>Nitzschia</i> sp. |
| <i>C.</i> sp. | <i>Stephanodiscus astraea</i> (Ehrenb.) Grun |
| <i>Epithemia</i> sp. | <i>S. niagarae</i> Ehrenb. |
| <i>Eunotia</i> sp. | <i>Synedra</i> sp. |
| <i>Fragilaria crotonensis</i> (A. M. Edw.) | <i>Tabellaria fenestrata</i> (Lyng.) Kütz. |
| Kitton | |

PROTOZOA

- | | |
|---|-----------------------|
| <i>Ceratium hirundinella</i> (O.F.M.) Schrank | <i>Euglena</i> spp. |
| <i>Diffugia</i> sp. | <i>Mallomonas</i> sp. |
| <i>Dinobryon</i> sp. | <i>Phacus</i> sp. |
| <i>Dinobryon sertularia</i> Ehrenb. | <i>Vorticella</i> sp. |

Chlorophyceae.—During the summer and early fall the green algae were unusually abundant both in total numbers and in variety of species. They were fairly abundant as late as December 1939 but after that time dropped off in numbers and in February, none was seen in the counts. Their numbers gradually increased during the spring until they were almost equal to the August maximum in the epilimnion in June. Only seven of the genera represented were present in any great numbers. The seasonal distribution of these seven forms is shown in fig. 5, where the mean of the counts at various depths is given. The vertical distribution of the green algae as a group is shown in fig. 6.

The most consistently present genus throughout the year was *Scenedesmus*, which was found in all the samples except those of January and February, and which reached a maximum of 458,000 per liter at 3 meters in August. *Ankistrodesmus falcatus* was also observed in the counts during every month except March, although it was never seen in great abundance, being present in maximum numbers in September (60,600 per liter at the surface). *Chlamydomonas* appeared in October and was present in small numbers during the remainder of the year, reaching a maximum in May (717,000 per liter at the surface). *Pediastrum* was observed in small numbers during the summer and as late as December; it appeared again in May. *Sphaerocystis Schroeterii* was abundant in summer, disappeared from the counts in the fall and reappeared in small numbers in the winter. It again was not seen in the spring but reappeared in June in small numbers. *Crucigenia tetrapedia* was very abundant in August (544,000 per liter at 5 meters) but after that showed a sharp drop in numbers and was not seen in the counts after October. *Oocystis* was also very numerous in August (380,000 per liter at the surface) but showed a similar drop in numbers and was not seen after December.

Myxophyceae.—The blue-green algae are known to be warm water forms in the main and this was confirmed by their seasonal distribution in Irondequoit Bay, where they were most numerous in August and September and were almost non-existent during the winter months, reappearing in small numbers in May. The blue-greens were with one exception always more abundant in the epilimnion. Of the six genera present, only one showed any long seasonal existence and four were present in abundance only in August. *Anabaena*, represented by three species, reached a maximum in December of 95,000 per liter at 5 meters. *Aphanizomenon flos-aquae* was very abundant in August (147,000 per liter at 5 meters) and then dropped off in numbers, finally disappearing from the counts in January. *Merismopedia* was found in abundance only during August (130,000 per liter at 5 meters). The other genera listed were seen only occasionally and in small numbers.

Diatomeae.—The diatoms were the dominant organisms in Irondequoit Bay during a large part of the year. The total numbers of individuals or colonies for all depths sampled reached a maximum of nearly 24,000,000 per liter in May. The fall maximum of 2,500,000 per liter occurred in November; in February the minimum of 81,000 per liter was observed. The vertical distribution of the diatoms as a group was varied; during the summer the greatest numbers were above the thermocline, while in the spring, maximum numbers were found in the hypolimnion. At most other times the vertical distribution was fairly regular.

Four genera were found during the greater part of the year. Of these, *Cyclotella* was found in all monthly samples and reached a maximum in May of 8,667,000 individuals per liter at 15 meters. Another maximum occurred in October (337,000 per liter at 23 meters). *Melosira crenulata* was also found during the year in all samples but was most abundant in August when it reached a maximum of 190,000 units per liter at 3 meters. It was again present in large numbers during October (311,000 units per liter at 10 meters). *Navicula* was found in small numbers throughout the year, except during August and December, its maximum occurring in October (25,900 per liter at the surface). *Stephanodiscus* (mainly *S. magareae*) appeared in October and was present in fair numbers through May, but was not found during the warm period. It was found in greatest abundance in November, when it was abundant at all depths with a maximum of 449,000 per liter at 5 meters. *Nitzschia* appeared in the fall and spring in small numbers, while *Amphora* appeared in March and was found in small numbers during the rest of the sampling period. *Asterionella formosa* was most abundant during the winter months, reaching a maximum of 22,000 five-rayed colonies per liter at 10 meters. *Meridion* was most abundant in August and April. *Synedra* had maxima in September and April and May (155,000 per liter at 10 meters in May).

In Chautauqua Lake, the diatoms were also abundant and were the dominant plankton forms. *Melosira* was found throughout the year with periods of maximum occurrence at the same times as in Irondequoit Bay, except that in Irondequoit there was no comparable spring maximum such as was observed in Chautauqua. *Fragilaria*, so common and abundant in Chautauqua, was

found in very small numbers in Irondequoit Bay and then rather infrequently. *Stephanodiscus* was the dominant winter diatom in both lakes.

Protozoa.—With the single exception of *Ceratium hirundinella*, protozoa were scarce in Irondequoit Bay. *Ceratium hirundinella* was not at all abundant in August, increased to a large number in September and remained abundant until November, when its numbers declined and it was not seen in December nor until it reappeared in very small numbers in the surface waters in June. In September it occurred in maximum numbers at 5 meters (242,000 per liter). In Chautauqua Lake, *Ceratium* appeared late in May and gradually increased to a maximum in September. *Dinobryon sertularia*, *Euglena* and *Diffugia* were present in small numbers in August and were only seen sporadically at other times in the fall and spring. In Chautauqua, a species of *Dinobryon* was the dominant winter protozoan, while *Glenodinium*, which was not found in Irondequoit, was present during the summer months. As in Chautauqua Lake, the greatest abundance of protozoans was in the epilimnion.

PRODUCTIVITY

Irondequoit Bay is even more eutrophic than Chautauqua Lake, a statement borne out by the extreme oxygen depletion in the hypolimnion during both summer and winter and in its high particulate organic matter. Centrifuged or particulate organic matter was determined at each depth sampled in each series throughout the year. The average of all depths (mean organic matter) is shown in fig. 5, and again in connection with organic phosphorus in fig. 3. The vertical distribution of organic matter is given in fig. 6.

In Irondequoit Bay, mean particulate organic matter ranged between 816 mgs/m^3 and 4,006 mgs/m^3 , with an average of 2,075. Chautauqua Lake ranged between 1037 and 2343 mgs/m^3 and averaged 1728, while Lake Mendota (Birge and Juday, 1922) averaged 1974 mgs/m^3 for the year. In Irondequoit Bay, the minimum surface determination was in February (410 mgs/m^3), which was partially due to dilution by melting ice, while the maximum readings were observed in November and May (3400 and 3500 mgs/m^3 respectively). The absolute extremes ranged between 410 (at the surface in February) and 10,270 at 23 meters in October. In Wisconsin, Birge and Juday (1934) found the surface waters to range between 230 and 12,000 mgs/m^3 with a mean of 1360. In Chautauqua Lake, the greatest amount of mean organic matter was found in late August with other maxima in spring and fall, while Irondequoit Bay showed only two maxima, one in spring and the other in the fall.

The vertical distribution of organic matter has been shown to be very variable in different lakes and in the same lake at different times of the year (Birge and Juday, 1934; Tressler, Wagner, and Bere, 1940), and the same condition was found to be true in Irondequoit Bay. Of the eleven series taken during the year, only three series showed the greatest amount of organic matter in the epilimnion (August, September, and May); all the other series showed maximum organic matter at or near the bottom. This may be partially explained in this case by turbulence in the hypolimnion creating a stirring up of the organic matter at the bottom, although in none of the samples was

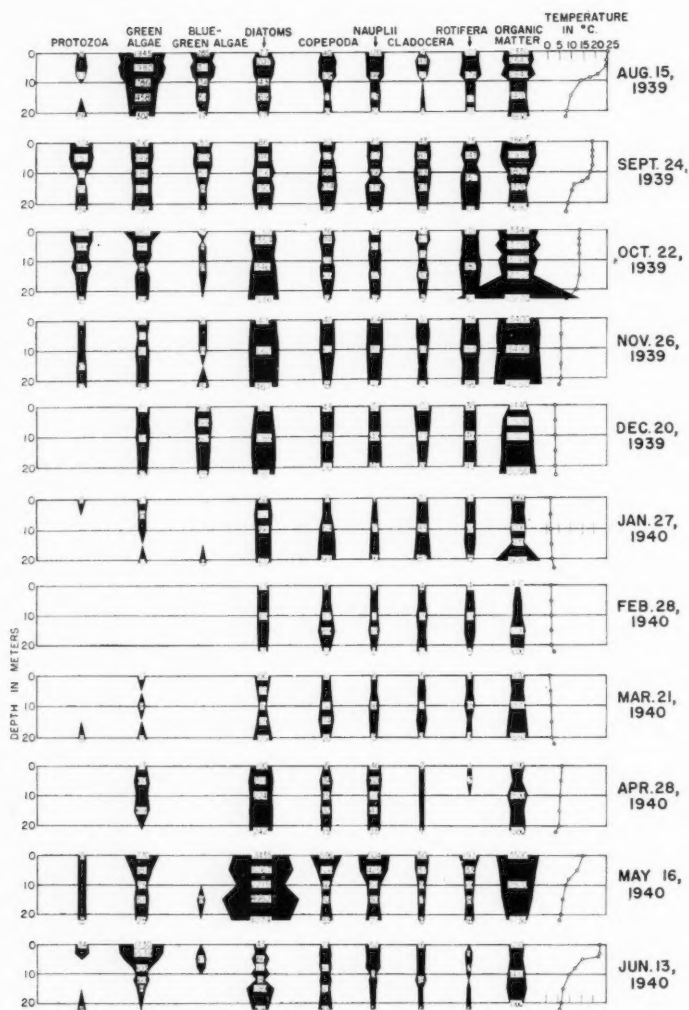


Fig. 6.—Vertical distribution of plankton groups and organic matter

there a visible indication of turbidity of the water. Density currents over the mud of the bottom also possibly contributed to an increase in organic matter. The August and September series showed a marked drop in organic matter below the thermocline and this was nicely correlated with a similar drop in plankton. In August the organic matter dropped from 2840 at 8 meters to 1430 mgs/m³ at 10 meters (Tressler and Austin, 1940).

When we compare the organic matter present in the surface water of Irondequoit Bay with that found in the smaller Finger Lakes to the south, the difference is very striking. On May 12, surface samples from five of the lakes were taken and organic matter determined with the following results: Conesus, 1850; Hemlock, 1590; Canadice, 1330; Honeyoye, 1150; Canandaigua, 960 mgs/m³. Four days later on May 16, the surface water of Irondequoit Bay contained 3500 mgs/m³ of particulate organic matter.

The area of deep water in Irondequoit Bay occupies a comparatively small region of the area of the lake, by far the greater part of the basin being of shallow depth with islands and marshy backwaters (fig. 1). This circumstance, as in Chautauqua Lake, considerably modifies the productivity picture when the organic matter is considered in relation to the area and volume of the entire body of water. In Irondequoit Bay, mean organic matter ranged from 51.4 to 252.0 kilograms per hectare. Table 3 shows the mean organic matter for all depths in kilograms per hectare for the eleven month period from August 1939 to June 1940. Chautauqua Lake during the same period

TABLE 3.—Mean organic matter for all depths in kilograms per hectare.

| Aug | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. |
|-------|-------|-------|-------|-------|-------|------|------|------|-------|------|
| 131.6 | 140.8 | 253.0 | 231.5 | 156.2 | 100.0 | 51.0 | 90.0 | 74.2 | 173.6 | 80.8 |

averaged 127.4 kilos per hectare and ranged between 73.6 and 166.5. Lake Mendota averaged 240 kilos per hectare for the year. Unfortunately, due to the necessary termination of the program of investigation, no determinations of organic matter were taken in other parts of the bay, so that comparisons with Chautauqua Lake on this basis can not be made. In Chautauqua Lake, horizontal surface samples showed higher averages than those taken in the deeper area (Tressler and Bere, 1938), and the same would be expected in Irondequoit Bay. It is to be hoped that further work on this important bay may be done by someone in the region before a channel is cut through to Lake Ontario and the bay ruined as far as extreme limnological conditions are concerned.

SUMMARY AND CONCLUSIONS

A limnological investigation of Irondequoit Bay, a closed-in area of Lake Ontario at the eastern outskirts of the city of Rochester, New York, was made between August 15, 1939 and June 13, 1940. Series of samples at various depths were taken monthly to determine the seasonal variations in physical, chemical, and biological factors. A summary of the findings is given below:

No oxygen was present during the summer in the deepest part of the lake (20 meters), below 10 meters depth. These conditions prevailed until the fall overturn in mid-November when oxygen was abundant at all depths. Oxygen was still absent at the bottom as late as mid-October.

Oxygen again became depleted during the winter (mid-March) in the bottom regions, a condition which shows extreme eutrophy. Oxygen was restored at the bottom during the spring overturn in April and May but by mid-June was again absent in the bottom water.

Free carbon dioxide was present in extremely high concentrations at the stagnation periods in early fall and late winter.

Hydrogen ion concentration and alkalinity showed normal fluctuations for a highly eutrophic lake. Mean alkalinity was correlated with conductivity. Very marked increases toward the bottom in alkalinity were observed in August and March.

Mean organic phosphorus showed a definite correlation with mean organic matter.

Specific conductivity was unusually high (600 units). Conductivity increased during the period from October to March, after which time it dropped off steadily.

Macroplankton was very abundant during the year except during a short period in January and February. Microplankton was very abundant during the summer and spring but became very scarce during the winter months. Diatoms were very numerous during May.

Particulate organic matter followed the plankton counts very closely, being greatest in the fall and spring and lowest in the winter. Particulate organic matter, in general, varied inversely with transparency.

Winter stagnation in Irondequoit Bay is believed to result from pollution entering by way of Irondequoit Creek and from large quantities of decomposing material on the bottom. Pollution in Irondequoit Bay is not believed to be serious enough to do more than increase the growth of plankton and certainly can not account for the decline in fishing.

The results of these investigations seem to indicate that stagnation conditions would be improved if a fairly deep channel were to be cut from the Bay to Lake Onatrio, thus allowing free circulation of lake waters into and out of the bay (as in nearby Sodus Bay).

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A List of the Trees and Shrubs of the Indiana Dunes State Park

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The Indiana Dunes State Park is located at Tremont, Porter County, Indiana, between Lake Michigan and the Chicago South Shore & South Bend Railroad and comprises 2182 acres.

I have been listing the species of trees found in this park since 1935. The list of species of trees shown at the end of this article may be regarded as complete. The total number of species, 69, is of particular interest because it is probably greater than in any other woodland in the United States of similar size.

The list of shrubs and woody vines includes those species that have come to my notice during the past few years. This list is not complete, especially in the genus *Rubus*, where there are three additional species that I have been unable to identify from the material collected, which does not fit any description in C. C. Deam's *Flora of Indiana*.

In the list of tree species, the columns to the right of the name contain supplemental data. The four columns following the name show the dimensions of the largest individual in the park so far as measurements have been taken. Where a species has shown a tendency to increase or decrease in numbers, that fact is indicated in the next to the last column. Notes on the occurrence of species represented by very few individuals in the park are referred to in the last column and explained at the end of the table.

The species shown in the tree list, found in this park, that are recognized as species of trees as distinguished from shrubs are those shown in the U. S. Forest Service's *Check List of the Native and Naturalized Trees of the United States*, issued in mimeograph form in 1944. In some cases, as explained in notes, the species do not attain tree size in this park.

Quercus velutina is the most common tree of the sand hills, and *Acer rubrum* is probably the most common tree of the lowlands. The Red Maple is more common here than in any other woodland that I have explored. A large area of the marsh extending from the center of the park to the eastern border is treeless, but is covered with an impenetrable shrubby growth of dogwoods, blackberries, raspberries and grapevines.

Seven species very common in Cook County, Illinois—*Juglans nigra*, *Quercus macrocarpa*, *Quercus ellipsoidalis*, *Celtis occidentalis*, *Crataegus mollis*, *Rhus glabra* and *Acer negundo*—are not found in this park. The reasons for their absence are worthy of investigation and comment.

The sandy soil probably inhibits the growth of *Juglans nigra*, *Quercus macrocarpa*, *Celtis occidentalis*, *Rhus glabra* and *Acer negundo*, all of which range widely. The sand left by the ice sheet in this region was of the silica

sand type, and not enough humus has accumulated to favor the growth of species that require a deep clay soil.

Quercus ellipsoidalis makes a very good growth on a site facing Lake Michigan with similar soil in Illinois and would certainly be found in this park if it were within the range of the species. There are trees at Dune Acres, Ind., little more than a mile southwest of this park, but no specimens have ever been found in this park, which is apparently just beyond its range.

Crataegus mollis is primarily a western species and is not found in northwestern Indiana.

Two species, *Castanea dentata* and *Staphylea trifolia*, have become extinct in the park in recent years.

There was a small colony of Chestnuts on the east bank of the east fork of Dunes Creek about 150 feet north of the railroad. In 1942 the largest tree had a diameter of 28", a circumference of 7'9" and a height of 54'. In 1944 this tree was found to be dead from the Asiatic chestnut blight. Another tree 16" in diameter continued to live until 1947, when it succumbed. Feeble second generation sprouts from the bases of two of the dead trunks persisted until the winter of 1951-2, when the last of the sprouts died.

In 1938 W. F. Durno showed me a colony of Bladdernuts west of Tremont Road and south of the creek. They seemed to be suffering from some sort of blight or fungus. I have seen no specimens of the species since 1941 and a search of the locality in 1951 failed to reveal any.

The following genera are represented in the two lists by five or more species: *Salix*, 11 species; *Crataegus*, *Rubus* and *Cornus*, 7 species; *Quercus* and *Rhus*, 5 species.

There is a total of 118 species of woody plants in the two lists.

SPECIES OF SHRUBS AND WOODY VINES

| | |
|--|--|
| <i>Juniperus communis depressa</i> | <i>Rubus flagellaris</i> |
| <i>Smilax rotundifolia</i> | <i>Rubus enslenii</i> |
| <i>Salix cordata</i> | <i>Rubus hispidus obovalis</i> |
| <i>Salix glaucophylloides glaucophylla</i> | <i>Rubus allegheniensis</i> |
| <i>Salix humilis hyporhiza</i> | <i>Rubus pensilvanicus</i> |
| <i>Salix gracilis textoris</i> | <i>Rosa palustris</i> |
| <i>Corylus americana</i> | <i>Rosa carolina Linnaeus</i> |
| <i>Celtis pumila</i> | <i>Rosa carolina villosa</i> |
| <i>Lindera benzoin Blume</i> | <i>Prunus pumila</i> |
| <i>Lindera benzoin pubescens</i> | <i>Rhus aromatica arenaria</i> |
| <i>Grossularia cynosbati</i> | <i>Rhus radicans vulgaris f. negundo</i> |
| <i>Ribes americanum</i> | <i>Rhus radicans rydbergii</i> |
| <i>Physocarpus opulifolius Maximowicz</i> | <i>Euonymus obovatus</i> |
| <i>Physocarpus opulifolius intermedius</i> | <i>Celastrus scandens</i> |
| <i>Spiraea alba</i> | <i>Ceanothus americanus</i> |
| <i>Aronia floribunda</i> | <i>Parthenocissus inserta</i> |
| <i>Aronia melanocarpa</i> | <i>Vitis labrusca</i> |
| <i>Crataegus biltmoreana</i> | <i>Vitis aestivalis Michaux</i> |
| <i>Rubus idaeus strigosus</i> | <i>Vitis aestivalis argentifolia</i> |
| <i>Rubus occidentalis</i> | <i>Vitis riparia sylvicola</i> |

Hypericum kalmianum
Cornus stolonifera
Cornus baileyi
Cornus rugosa
Cornus obliqua
Cornus racemosa
Gaultheria procumbens
Arctostaphylos uva-ursi

Gaylussacia baccata
Vaccinium vacillans Torrey
Vaccinium vacillans crinitum
Vaccinium angustifolium laevifolium
Lonicera bella
Lonicera dioica
Viburnum acerifolium
Viburnum trilobum

SPECIES OF TREES

G—Average annual increment of circumference in inches.

Change { I—Increasing.
 { D—Decreasing.

| | Diameter | Circumference | Spread | Height | G | Change | Note |
|--|----------|---------------|--------|--------|------|--------|------|
| <i>Pinus strobus</i> | 2' 5" | | | | | D | .... |
| <i>Pinus banksiana</i> | 1' 1" | 3' 6" | 21' | 28' | .... | D | .... |
| * <i>Juniperus communis</i> Linnaeus | 3" | 10" | 4' | 16' | .12 | .. | .... |
| <i>Juniperus virginiana</i> | | | | | | D | .... |
| <i>Juglans cinerea</i> ..... |  |  |  |  |  |  | .... |
| <i>Carya cordiformis</i> | 2' 1" | 6' 7" |  |  |  |  | .... |
| <i>Carya ovata</i> ..... |  |  |  |  |  |  | .... |
| <i>Populus tremuloides</i> | 11" |  |  |  |  |  | .... |
| <i>Populus grandidentata</i> | 9" |  |  |  |  |  | .... |
| <i>Populus tacamahaca</i> Miller ..... |  |  |  |  |  |  | .... |
| <i>Populus tacamahaca michauxii</i> | 1' 1" |  |  |  |  |  | .... |
| <i>Populus deltoides</i> | 3' 6" |  |  |  |  |  | .... |
| <i>Salix nigra</i> ..... |  |  |  |  |  |  | .... |
| <i>Salix amygdaloides</i> | 1' 5" | 4' 6" | 34' | 50' |  |  | .... |
| <i>Salix lucida</i> | | | | | | | 2 |
| <i>Salix interior</i> ..... |  |  |  |  |  |  | .... |
| <i>Salix discolor</i> Muehlenberg ..... |  |  |  |  |  |  | .... |
| <i>Salix sericea</i> | | | | | | | 4 |
| <i>Salix bebbiana</i> ..... |  |  |  |  |  |  | .... |
| <i>Carpinus caroliniana</i> | 7" |  |  |  |  |  | .... |
| <i>Ostrya virginiana</i> ..... |  |  |  |  |  |  | .... |
| <i>Betula populifolia</i> | 4" | 1' 1" | | | | | 11 |
| <i>Betula papyrifera</i> | 10" | 2' 5" | | | | D | 3 |
| * <i>Alnus rugosa americana</i> | 6" | 1' 7" | 15' | 34' | .2 |  | .... |
| <i>Fagus grandifolia</i> | 2' 1" | | | | | D | .... |
| <i>Quercus borealis</i> Michaux fils | 2' 8" | | | | | | 5 |
| <i>Quercus borealis maxima</i> | 2' 9" |  |  |  |  |  | .... |
| <i>Quercus palustris</i> | 2' 1" | | | | | I | .... |
| <i>Quercus velutina</i> | 2' 5" | | | | | I | .... |
| <i>Quercus alba</i> Linnaeus | 2' 10" |  |  |  |  |  | .... |
| <i>Quercus alba latiloba</i> | 2' 6" |  |  |  |  |  | .... |
| <i>Quercus bicolor</i> | 2' 4" |  |  |  |  |  | .... |
| <i>Ulmus americana</i> | 3' 2" |  |  |  |  |  | .... |
| <i>Ulmus fulva</i> | | | | | | | 6 |

* The tree whose dimensions are shown is the largest native tree of its kind in the United States.

SPECIES OF TREES (concluded).

| | Diameter | Circumference | Spread | Height | G | Change | Note |
|--|-----------|---------------|--------|--------|-------|--------|-------|
| <i>Morus iubra</i> | 2' 5" | ..... | ..... | ..... | ..... | - | 7 |
| <i>Liriodendron tulipifera</i> | 3" | ..... | ..... | ..... | ..... | I | ..... |
| <i>Asimina triloba</i> | 1' 1" | ..... | ..... | ..... | ..... | I | ..... |
| <i>Sassafras albidum</i> | 5" | 1' 3" | 25' | 26' | .2 | - | ..... |
| <i>Hamamelis virginiana</i> ..... | ..... | ..... | ..... | ..... | ..... | I | ..... |
| <i>Platanus occidentalis</i> | 4" | 1' 2" | 12' | 36' | ..... | - | ..... |
| * <i>Malus coronaria</i> | 6" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Malus ioensis</i> | 9" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Amelanchier arborea</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Crataegus crus-galli</i> ..... | ..... | ..... | ..... | ..... | ..... | - | 8 |
| <i>Crataegus punctata</i> ..... | ..... | ..... | ..... | ..... | ..... | D | 9 |
| <i>Crataegus pruinosa</i> | 4" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Crataegus macrosperma</i> Ashe ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Crataegus pedicellata</i> | 4" | ..... | ..... | ..... | ..... | - | 10 |
| <i>Crataegus calpodendron</i> ..... | ..... | ..... | ..... | ..... | ..... | D | ..... |
| <i>Prunus pensylvanica</i> | 9" | 2' 4" | ..... | ..... | ..... | - | ..... |
| <i>Prunus virginiana</i> Linnaeus | 3" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Prunus serotina</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Zanthoxylum americanum</i> | 2 1/16" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Ptelea trifoliata mollis</i> | 3" | ..... | ..... | ..... | ..... | - | ..... |
| * <i>Rhus typhina</i> | 5" | 1' 4" | 17' | 36' | ..... | D | ..... |
| * <i>Rhus copallina</i> | 4" | 1' 2" | 18' | 27' | .5 | - | ..... |
| <i>Rhus vernix</i> | 5" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Ilex verticillata</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Acer saccharum</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Acer saccharinum</i> ..... | ..... | ..... | ..... | ..... | ..... | - | 1 |
| <i>Acer rubrum</i> | 2 4" | 7' 4" | ..... | ..... | ..... | I | ..... |
| <i>Tilia americana</i> | 3' | 9' 6" | ..... | ..... | ..... | - | ..... |
| <i>Nyssa sylvatica</i> | 2' 4 1/2" | ..... | ..... | ..... | ..... | I | ..... |
| <i>Cornus florida</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Cornus alternifolia</i> ..... | ..... | ..... | ..... | ..... | ..... | D | ..... |
| * <i>Fraxinus nigra</i> | 2' 1" | 6' 5" | ..... | ..... | ..... | - | ..... |
| <i>Fraxinus americana</i> | 2' 5 1/2" | ..... | ..... | ..... | ..... | - | ..... |
| <i>Fraxinus pennsylvanica</i> Marshall ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Fraxinus pennsylvanica lanceolata</i> ..... | ..... | ..... | ..... | ..... | ..... | - | ..... |
| <i>Cephalanthus occidentalis</i> | 4" | ..... | ..... | ..... | ..... | - | ..... |
| * <i>Sambucus canadensis</i> | 3" | 9" | 13' | 13' | ..... | - | ..... |
| <i>Viburnum lentago</i> | 6" | 1' 9" | 21' | 26' | .2 | - | ..... |
| <i>Viburnum prunifolium</i> ..... | ..... | ..... | ..... | ..... | ..... | I | 12 |

NOTES.—1. Very rare; I have seen only 3 or 4 trees. 2. Several bushy specimens on the prairie just west of the east fork of Dunes Creek. 3. Two trees about 75 feet south of No. 2 trail in the east central part. 4. Rare and not arborescent in the park. 5. One tree on the south side of No. 10 trail in the Pinery. 6. A few trees at the foot of the west slope of the Big Blow-out. 7. In intervals south of Mt. Tom. 8. One small tree on No. 2 trail west of a bridge in the western part. 9. Two or three trees in dense woods in the southwestern part. 10. Two trees south and southwest of the Wilson Shelter Canteen near the road. 11. One tree 11 feet south of No. 2 trail and about 400 feet west of its junction with No. 5. 12. Probably not arborescent in the park.

A Study of an Invasion by Red Maple of an Oak Woods in Southern Wisconsin

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The few remaining oak woods in southern Wisconsin which have escaped disturbance by fire, grazing, or extensive cutting present an unusual opportunity for studies of successional relationships.

Although maple-basswood (*Acer saccharum-Tilia americana*) is the climatic climax community for the westward extension of the central deciduous forest (Braun, '47), it has been noted that Indians using fires as hunting adjuncts successfully maintained a number of large areas in oak-opening and prairie disclimax until a century ago (Cottam, '49). A study of the records of the original land survey conducted in 1832-'35 has shown that most of Dane County was either oak-opening, prairie, or marsh (Ellarson, '48). Three small terminal maple forests existed in areas protected by lakes from fire driven by the prevailing southwest winds.

Settlement of the region resulted both in the clearing for agricultural purposes of a major proportion of the area occupied by oak-opening and in a cessation of fire. The few remaining uncleared areas have developed into close-canopied oak forests of varying composition (Curtis and McIntosh, '51).

The stand of oak which comprises the subject of this study is located in Sections 7 and 8, T-9-N, R-8-E, in northwestern Dane County, Wis. The entire oak woods occupies roughly a half square mile and falls within a region which, at the time of the original land survey, was oak-opening (Ellarson, '48).

The topography of the area is gently to moderately rolling, a result of glaciation. Nine miles to the west is a terminal moraine which marks the edge of glaciation and the beginning of the Wisconsin Driftless Area. It is believed by some investigators that after retreat of the glacier, maple and basswood spread throughout the region from a Pleistocene refuge in the Driftless Area (Braun, '47). The soil is Miami silt loam. The oak woods was studied with particular attention to several distinct areas occupied by red maple (*Acer rubrum*).

The author would like to take this opportunity to express his gratitude for the constant interest and assistance provided by Prof. John T. Curtis from the time of initiation of the project to its completion.

Method.—Visual inspection of the woods, particularly during fall when leaf colors are brilliant, conveys the definite impression that red maples are coming into the understorey in at least five strikingly demarked areas. At the center of each of these areas, one or more red maple trees of considerable size are to be found, and beneath these trees and for a distance around them the herbaceous and shrubby vegetation is nearly absent or extremely thin.

The rapid decomposition of the litter from the surface of the ground also serves to set the areas apart from the oak-dominated portions of the forest. At a rather specific distance from the center of each area the undergrowth increases in density and the influence of the red maples begins to decline.

In studying the area it was considered advisable to take samples in strips of continuous quadrats radiating from the center of each of the red maple stands. An attempt was made to traverse a distance beyond the edge of the red maple stands equal to the distance from the center to the edge. The size of two stands made strips of 15 contiguous quadrats from the centers necessary; strips of 10 quadrats were considered adequate for three stands. Four strips were taken from the center of each of four stands, and seven strips were taken from a circle around the center of the largest stand.

Quadrats were circular and 20 feet in diameter. To avoid the necessity of counting maple seedlings in the entire area of each 20-foot quadrat, a smaller circle of 12 feet in diameter was enclosed in each quadrat for density counts of seedlings and for shrub frequency counts. A somewhat subjective choice of strip direction was made necessary at times because of small areas

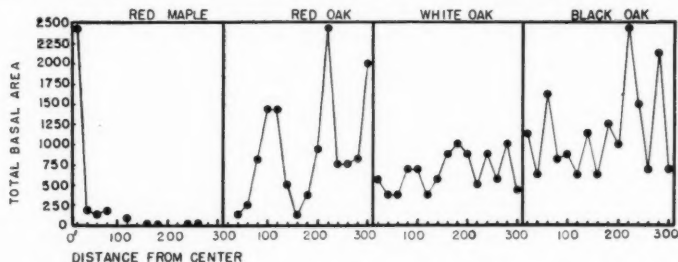


Fig. 1.—Comparisons of basal areas of oaks and red maple. The total basal area represents the sum of basal areas in all 23 quadrats at each designated distance from the center of the stands.

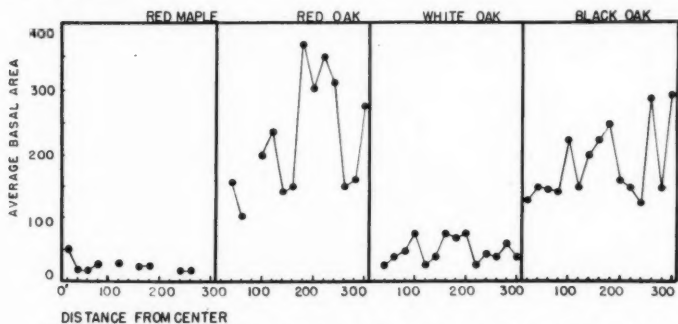


Fig. 2.—Average basal areas of oaks and red maples in all quadrats at the designated distance from the center of the stands.

of recent cutting, gullies, and roads. In most stands, however, strips followed the chief compass points.

Result.—In total and average basal area (Figs. 1, 2), the forest is dominated by black oak (*Quercus velutina*) and red oak (*Quercus rubra*). In total number of trees, however, the white oaks (*Quercus alba*) occupy the leading position (Fig. 3).

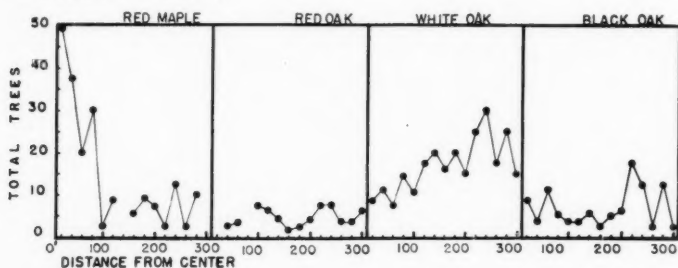


Fig. 3.—The total number of trees more than an inch in diameter in all quadrats at the designated distance from the center of the stands.

It should be noted that the red maple stands are on definitely delimited areas as far as the shrub vegetation is concerned (Figs. 4 and 5). Shrubs are restricted in frequency and in number of species within the maple stands, shown by presence lists taken in each quadrat. The most marked difference in frequency between the oak-dominated and the maple-dominated areas was noted in grey dogwood (*Cornus racemosa*), alternate leaved dogwood (*Cornus alternifolia*), and raspberry and blackberry (*Rubus* spp.). All are abundant in the oak-dominated areas but infrequent in the centers of the areas dominated by maple.

These factors indicate that red maple encroachment is not a chance or haphazard event. The first maples came into the area at about the same time as the red and white oaks, and the fact that the maples have only recently begun to spread from the few trees at the center of each stand indicates that the conditions necessary for successful ecesis of red maples have only recently been attained. The red maples which now form the center of the spreading red maple stands vary in basal areas from 330 to 40 and fewer square inches, and their seedlings dominate reproduction in each stand (Fig. 6).

Discussion.—In forests of the extreme eastern portion of the United States, red maple is found in oak (formerly oak-chestnut) associations (Cain, '36) and in hemlock and hemlock-beech associations (Lutz, '30). In the forest described by Cain, which is located on Long Island, red maple is pictured as having a density out of proportion to its basal area percentage due to the small number of trees attaining the larger size groups.

Cain describes red maple as having a strong reproduction but low survival in the older ages. Cain ('38) suggests that the red maple swamp



Fig. 4.—View of part of the largest area dominated by red maple, showing the lack of shrub and herb vegetation and the widely dispersed oaks. The photographs were taken in fall when leaf litter was thick.

forest type of the eastern United States be recognized as a distinct association from an academic and phytosociological point of view. In *Forest Cover Types of the United States* ('32), the Society of American Foresters, according to Cain, describes its Type 26 as black ash-American elm-red maple, and points out that in New England red maple often predominates and may be found in pure stands. It is described as occupying "moist to wet muck or shallow peat soils in swamps, gullies, and small depressions of slow drainage or in elongated areas along small sluggish streams, occasionally covering extensive swamps."

Lutz ('30) describes a hemlock-beech association which he believed somewhat less advanced than the climax of the region, and also what he terms a hemlock consociation which represented "an environmental or physiographic climax which was probably of fairly common occurrence on the moister soils in the primeval forest." Although red maple was found in each, it was definitely more important in the hemlock-beech association where it was classed with hemlock, beech, and black birch not only in a smaller size categories but also in the larger. In this study, conducted in northwestern Pennsylvania, red maple was highest in abundance and second in frequency in the size class 0-9 feet high. In the size class 3.5-9.5 DBH it ranked fourth in abundance and fifth in frequency.

Cain ('35) describes red maple in a Michigan forest as having a frequency of 20 per cent. The forest was a virgin beech-maple-hardwood. He



Fig. 5.—View from the edge of a maple area and into part of the oak-dominated woods, showing the increase in shrub and herb frequency and the density of oak trees.

adds that "species represented by a scattering of older trees, and with sufficient reproduction to maintain their role in the forest, although a minor one, are *Ulmus americana*, *Acer rubrum*, and *Quercus borealis* var. *maxima*."

In a maple-basswood forest in northwestern Wisconsin, Egger ('38) described red maple as having a frequency of 14 per cent among the trees more than one foot tall in a woods believed to be typical of the regional climax.

In a study of upland conifer-hardwood forest, Brown and Curtis ('52) found that *Acer rubrum* "has, perhaps, the broadest amplitude of environmental tolerance of any tree found in northern Wisconsin." They ascribe to red maple a climax adaptation value of 6. This places red maple slightly higher than midway in the successional sequence of the region. Brown and Curtis locate jack pine (*Pinus banksiana*) at the pioneer end of succession with a climax adaptation value of 1, and give the climax beech-maple (*Fagus grandifolia*-*Acer saccharum*) each a value of 10. In northern Wisconsin red maple could be considered an indicator of the transition stage in which the pine forest gives way to the hardwood.

In the stand that makes up the subject of the present study, it seems probable that red maple will now continue a gradual spread throughout the area. In at least two other forests in southern Wisconsin it has been noted that the successional stage for transition from oak to red maple has been reached. In an area known as Stewart's Woods, Cottam ('49) made a

study which indicated that the oaks in well-protected areas were one-generation stands, with lack of oak reproduction at the present time, and with a notable presence of elm, red and sugar maple, and basswood. In the Devil's Lake State Park forest area, which is within 30 miles of the area making up the subject of the present study, the author and others have observed a striking understory of red maple in an oak forest. A study of the Devil's Lake forest by Curtis and associates (Unpub.) has shown that mature red

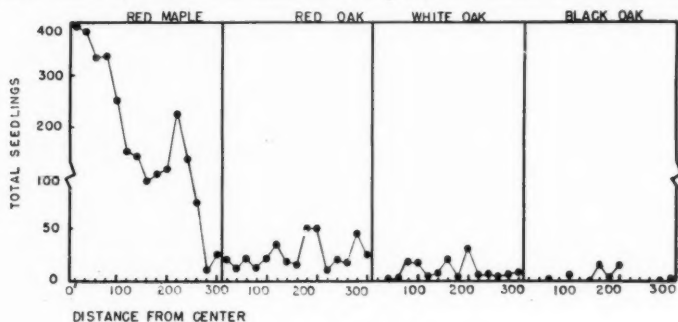


Fig. 6.—Total seedlings in all quadrats at the designated distance from the center of the stands.

oak has a relative frequency of 61.2 per cent, a relative density of 79.2 per cent, and a relative dominance of 84.1 per cent, giving an importance index of 224.5. On the other hand, the mature red maple in this forest have a relative frequency of 2 per cent, a relative density of .8 per cent, and a relative dominance of .4 per cent, for an importance index of only 3.2. Among the saplings, there were an average of 97 red maple saplings in a sample of 120, for a relative density of 80.8 per cent. There were no red oak saplings in the sample. This overwhelming preponderance of red maple saplings indicates the successional stage.

The red maple, therefore, appears to be an intermediate tree, and appears to play a dynamic role in forest development in southern Wisconsin much the same as it does in the region where it reaches greater importance, as already demonstrated in northern Wisconsin and in several eastern states.

Conclusion.—The following conclusions can be drawn from the literature and the present study:

Red maple apparently occupies a somewhat different ecological niche in the forest of southern Wisconsin than in the forests of the more eastern United States and the upland conifer-hardwood forests of the north-central United States. In an eastern oak (formerly oak-chestnut) association on Long Island it is seldom represented in the large size groups. The Society of American Foresters describes red maple as occupying moist to wet muck or shallow peat soils. In pure stand it is the occupant of a Long Island swamp forest. In northwestern Pennsylvania it is found in a virgin hemlock-

beech association and a hemlock consociation. In a climax maple-basswood forest studied in northern Wisconsin, red maple has a frequency of 14 per cent. In the upland conifer-hardwood forest of northern Wisconsin it is described as having a climax adaptation value of 6, and could be considered an indicator of the transition stage from pine to hardwood.

In the five small stands of red maple which form the subject of this study, the red maples have held a place of dominance over both the white and the red oaks for some years. In basal area and total number of trees, only the black oaks seem not to have been greatly influenced by the presence of red maple. This would be explained by the fact that black oak occupied the area prior to red maple invasion, first as the original occupant (probably with bur oak) of the oak-opening forest and later as the pioneer occupants of the closer-canopied forest.

Red maple is found in oak forests of southern Wisconsin which have attained the stage prerequisite for transition to a maple-basswood climax forest.

The conditions in the forest have only recently reached the stage where red maple will be able to compete with other species throughout the general forest area.

It seems probable that red maple will continue a gradual spread throughout the forest.

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Revegetation of Alkali Flood Plains Adjoining the North Platte River, Garden County, Nebraska¹

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The rapidity with which formerly cultivated land is invaded by certain native grasses is a striking feature of the salt flats or flood plains adjoining the North Platte River in western Nebraska. The general floristics of several areas removed from field crops usage are described briefly in this paper. Those referred to were considered representative of grasslands of the various ages examined during 1935, and from which the trends of revegetation upon this particular soil type can be inferred. Past histories were obtained from farm operators in the region where the areas were located. Most of these sites were revisited during the summer of 1947 with the thought of compiling additional observations concerning the changes that might have occurred during the intervening years. However, some previously studied areas had been returned to field crops, while others were so closely grazed that compilation of additional information was impossible.

LITERATURE REVIEW

Weaver and Fitzpatrick (1934) refer to the salt flats only briefly in their discussion of "The Prairie." Aside from giving the general features of the type of habitat in which *Distichlis* grows, together with some of its growth characteristics and the accompanying species, no detailed information on the species was included in their discussion.

Hanson and Whitman (1938) considered areas of moderately high alkalinity upon which salt-grass, and associated grasses and forbs, occurs in North Dakota. Data were presented relative to the profile, structure, and chemical composition of the soil, as well as to the flora. Generally, the soil profiles are poorly defined, highly alkaline, high in carbonates, and low in organic matter. The number of species occurring on such locations was found to be comparatively low. *Distichlis stricta* (Torr.) Rydb. and *Puccinellia airoides* (Nutt.) Wats. and Coult. were the dominant grasses with *Agropyron Smithii* Rydb. and *Hordeum jubatum* L. abundant in some areas.

Frolik and Shepard (1940) found that *Distichlis stricta* formed almost pure stands of rather open sod in favorable Nebraska Sand Hill lowlands. However, with moderate grazing the stand of this species thickens whereas with complete protection from grazing the stand becomes less dense. *Distichlis* made up approximately 40 per cent of the plant cover of alkaline meadows while *Hordeum jubatum*, the second most common component, accounted for an additional 10.5 percent. *Sporobolus airoides* (Torr.) Torr., a rather common species of the meadows observed by the writer, apparently did not occur here, at least not in recordable abundance.

¹ Observations reported were compiled during the summer of 1935 when the writer was employed as Junior Botanist, Soil Conservation Service, U. S. Dept. of Agriculture.

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DESCRIPTION OF SITES

Location.—Most of the areas referred to lie north of the North Platte River in the immediate vicinity of Oshkosh, Garden County, Nebraska. One area, a virgin meadow located about seven miles west of Oshkosh, was situated on the south side of the river. Virgin meadows are considered here as those that show no evidences of former cultivation and which local persons had no recollection of ever having been under cultivation. These might have been altered somewhat through the years since settlement from repeated grazing by cattle or from mowing for hay. Such activities have perhaps not altered the species composition greatly though they may have altered the proportions of the various species quite materially. The natural climax vegetation of the upland areas of this region is one of the short-grass type.

Soil type.—All of the observations were made in areas characterized by Laurel silt loam which "consists of brown, dark-brown, or grayish-brown sticky and plastic heavy silt loam, from 8 to 10 inches deep." This grades into a lighter colored grayish-yellow or grayish-brown more friable loam. The lower part of the subsoil, which continues to a depth of about three feet, grades into a fine gravel and sand. Both the topsoil and subsoil are highly calcareous. This soil type occurs only on the first bottoms along the North Platte River and Blue Creek. The largest and most typical area is west and south of Oshkosh. The land, which is subject to inundation during periods of high water, is flat, and drainage, in general, is poor (Wolfanger et al., 1929).

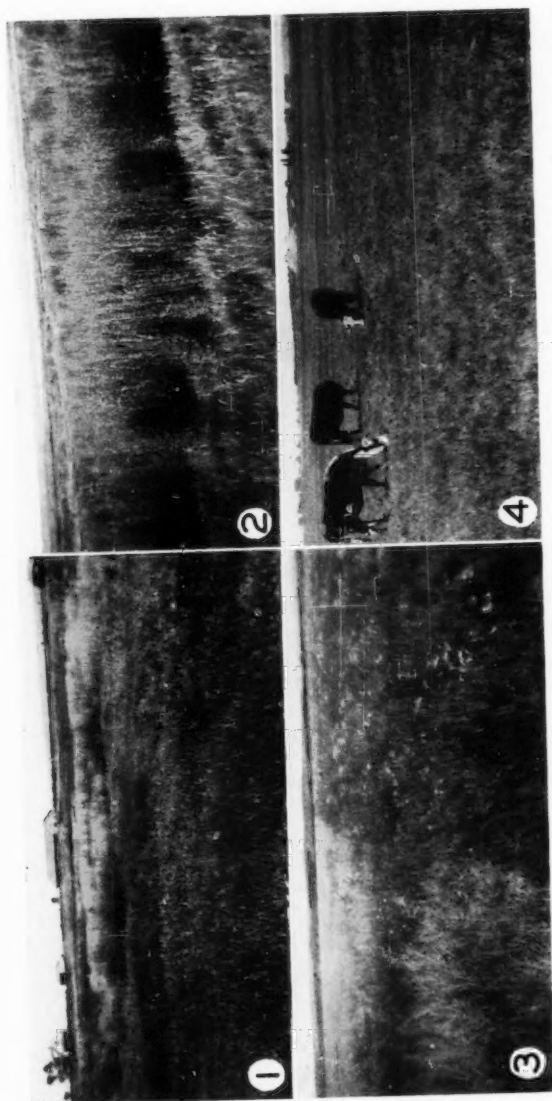
Soil analysis.—Soil samples were taken at the surface and at six- and twelve-inch depths. Tests for soil acidity and available phosphorus, made by Dr. L. C. Kapp, currently of the Texas Agricultural Experiment Station, are given in table 1.

The soils of all the locations sampled were high in alkalinity as well as generally very low in available phosphorus. The greater deficiency of available phosphorus of areas once under cultivation is evident in meadow III and, but slightly less so, in meadow IV. This may have been due to an original low total phosphorus content, or the phosphorus may have been rendered unavailable by a high calcium carbonate content, or if available it may have been exhausted recently by a growing crop. It would appear as though the alkalinity is somewhat higher on areas formerly cultivated than upon the virgin areas.

VEGETATIONAL DEVELOPMENT

First year.—A field located in NE $\frac{1}{4}$, Sec. 7, R 43W had been plowed and a seed bed prepared during the spring of 1935. Nothing had been seeded, however, and during late July and early August the following species were well established: *Plantago eriopoda* Torr., *Kochia trichophylla* Stapf., *Hordeum jubatum*, *Solanum rostratum* Dunal, *Iva ciliata* Willd., *Cleome serrulata* Pursh., *Melilotus alba* Desr. and *Suaeda depressa* (Pursh.) S. Wats. In addition to these weedy species certain perennial grasses were already in evidence. These included *Panicum virgatum* L., *Agropyron Smithii* and *Distichlis stricta*.

Third year.—Among areas that had been left idle since 1932 was one



Figs. 1-4.—1. Reverted farm land in the third year following cultivation, with *Distichlis* supplanting *Kochia*-*Hordeum* association. 2. Reverted farm land in the third year following cultivation, with *Distichlis* replacing *Kochia* and *Hordeum*. 3. Climax *Sporobolus airoides*-*Distichlis stricta* association on left. Scattered plants of *Hordeum jubatum* are evident in dense stands of *Distichlis* on right which was under cultivation eight years previously. 4. Pasture dominated by *Sporobolus airoides* and *Distichlis stricta* in twenty-ninth year following cultivation.

1. Reverted farm land in the third year following cultivation, with *Distichlis* supplanting *Kochia*-*Hordeum* association. 2. Reverted farm land in the third year following cultivation, with *Distichlis* replacing *Kochia* and *Hordeum*. 3. Climax *Sporobolus*

located in the SE $\frac{1}{4}$ Sec. 20, T 19N, R 44W. Sugar beets had been grown the last year this field was under cultivation. During July, 1935, it was covered with a mottled patchwork of *Kochia trichophylla* and *Hordeum jubatum*, below and among which were areas completely dominated by *Distichlis stricta*. Scattered individuals of *Iva ciliata*, *Helianthus annuus* L., *Panicum capillare* L., *Melilotus alba*, *Polygonum ramosissimum* Michx., *Eragrostis cilianensis* (All.) Lutati, *Agropyron Smithii*, *Xanthium* sp., and *Lactuca* sp. were encountered in some abundance (Figs. 1, 2).

Eighth year.—An area (SW $\frac{1}{4}$, Sec. 35, T 17N, R 44W), last under cultivation during 1928 when oats and watermelons were grown, is shown in fig. 3. It was covered with a well-established turf of *Distichlis stricta* in which

TABLE I.—The pH value and amount of available phosphorus in Laurel silt loam, Garden County, Nebraska.

| Location | Sampling depth | pH | Available Phosphorus* |
|-------------------|----------------|---------|-----------------------|
| I-1 (virgin) | Surface | 8.2 | 4 |
| | 6" | 8.8-9.0 | 4 |
| | 12" | 8.6 | 4 |
| I-2 (virgin) | Surface | 8.5 | 4 |
| | 6" | 8.8 | 4 |
| | 12" | 9.1 | 4 |
| II-1 (virgin) | Surface | 7.1 | 4 |
| | 6" | 8.0 | 8 |
| | 12" | 8.0-8.3 | 8 |
| III-1 (17 yr.) | Surface | 7.6 | -4 |
| | 6" | 8.6 | trace |
| | 12" | 8.8 | 4 |
| IV-1 (20 yr.) | Surface | 9.2 | -4 |
| | 6" | 9.2-9.3 | -4 |
| | 12" | 9.2 | -4 |
| IV-2 (20 yr.) | Surface | 9.0 | trace |
| | 6" | 9.2 | trace |
| | 12" | 9.6-9.8 | trace |

* Pounds per acre in top six inches of soil.

occurred a few small colonies of *Agropyron Smithii*, *Panicum virgatum* and *Sporobolus airoides*, the latter sometimes forming colonies several feet in diameter. Only occasional plants or colonies of *Kochia* and *Hordeum* remained. This area was bordered on either side by the climax association, a condition well shown in the figure referred to. The climax area to the left is composed of a uniform stand of *Sporobolus* and *Distichlis*; the reverted farm land on the right is made up of a dense stand of *Distichlis* broken only by scattered individuals or colonies of salt saccaton and *Hordeum jubatum*.

Seventeenth year.—Few fields were located, concerning which the past history was certain, that had been allowed to revert to and remain in grass-land for extended periods of time. One such area was located in the S $\frac{1}{2}$,

SW $\frac{1}{4}$, Sec. 28, T 17N, R 44W. Previous cultivations were discernible only from the dead furrows that marked the sides of the formerly cultivated area that made up approximately a third of the forty-acre field. Reestablishment of *Distichlis* and *Sporobolus* might have been accelerated somewhat since ample seed for reseeding was probably produced on adjacent undisturbed areas. During 1947 this location was densely covered with salt grass and salt saccaton while scattered individuals or clumps of *Hordeum jubatum* remained relatively common (Fig. 4).

Edaphic climax.—Numerous meadows that represented the edaphic climax of the salt flats were examined. Representative of these were the SW $\frac{1}{4}$, NE $\frac{1}{4}$ and the SE $\frac{1}{2}$, Sec. 29, T 17N, R 44W, and the NW $\frac{1}{4}$ and the SE $\frac{1}{4}$, Sec. 23, T 17N, R 45W. These are referred to in the accompanying table as I-1, I-2 and II-1. The association was dominated by a mixed stand of *Distichlis* and *Sporobolus*. The sub-dominants were *Agropyron Smithii* and *Juncus balticus* var. *littoralis* Engelman (*J. litorum* Rydb.) together with scattered colonies of *Panicum virgatum*. Common ruderals and forbs included *Plantago eriopoda*, *Asclepias speciosa* Torr., *A. verticillata* L., *Apocynum cordigerum* Greene, *A. sibiricum* Jacq., *Triglochin maritima* L., *Eustoma Russellianum* (L.) Griseb., *Solidago Lunellii* Rydb., *Ambrosia psilostachys* D.C., *Helianthus Maximiliani* Schrad., *Glycyrrhiza lepidota* (Nutt.) Pursh., *Polygonum ramosissimum*, *Equisetum* sp. and *Senecio* sp.

SUMMARY

Distichlis stricta and *Sporobolus airoides* form the edaphic climax on the highly alkaline and phosphorus deficient soils adjoining the North Platte River in western Nebraska. Areas formerly under cultivation appear to have slightly higher pH values and lower available phosphorus than do virgin areas. Under the conditions that existed prior to the time these observations were made, it can be inferred that the edaphic climax species had become reasonably well established in from 20 to 30 years.

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Desmodium paniculatum (L.) DC. and *D. viridiflorum* (L.) DC.¹

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The status of two species complexes—*Desmodium*, series *Stipitata* Schub.—is reviewed in the present paper. These complexes, centering about *D. paniculatum* and *viridiflorum* respectively, are among the most common representatives of the genus in eastern North America. They have been subjected to several interpretations in recent literature. It has appeared desirable, therefore, to obtain data elaborating the nature of morphological variability of the groups, and to employ such data in the formulation of taxonomic conclusions.

Herbarium material employed consisted of the writer's personal collections, as well as specimens borrowed from the Missouri Botanical Garden, the Chicago Museum of Natural History and Iowa State College Herbarium. Courtesies of the respective curators are acknowledged with thanks. I am especially obligated to Mary M. Rehm who prepared the charts accompanying this paper.

DESMODIUM PANICULATUM COMPLEX

For present purposes, the *Desmodium paniculatum* complex is defined as including plant populations of the series *Stipitata* Schub. which possess short pedicels and glabrate or pubescent (but not velvety-tomentose or glaucous), thin to moderately reticulate leaves. The number of species treated ranges from 2-5 in current botanical manuals (e.g. Small, 1933; Deam, 1940; Schubert, 1950a).

The members of this group are relatively consistent as regards loment characters but are diverse in leaflet shape, pubescence and petiole length. Most authors refer glabrate or moderately hairy forms with narrow leaflets to *Desmodium paniculatum* (L.) DC., and hairier plants with broad leaflets are termed *D. dillenii* Darl. (*D. perplexum* Schub. in part). A sharp line of demarcation between the two species is, however, difficult to determine, a fact which has been noted by several workers (Deam, 1940; Fassett, 1939; Schindler, 1926). The epithets, *angustifolium* T. & G., *chapmani* Britt., *pubens* T. & G., *glabellum* Michx., *epetiolatum* Schub., are employed for various phenotypes within the group—in a specific sense or as varieties of *D. paniculatum*.

Two hundred two specimens representative of the *Desmodium paniculatum* complex were examined in the present study. Tabulations, on a quantitative (measurement) or qualitative (choice between two and more alterna-

¹ Journal paper no. J-2042, of the Iowa Agricultural Experiment Station Project 1073.

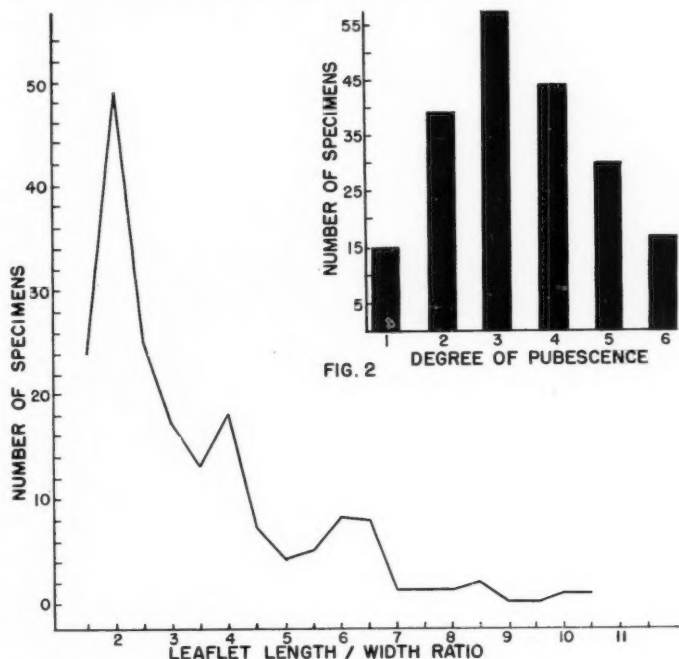


FIG. 2

Figs. 1-2. *Desmodium paniculatum* complex.—1. Variation in leaflet proportions.
2. Variation in pubescence.

tives) basis, were made of several variable characteristics including those features said to have value in classifying the species. These characters include: (1) length-width proportions of terminal leaflets, (2) density and type of pubescence on lower and upper surface of leaflets, (3) petiole length, (4) degree of leaf reticulation, (5) persistence of stipules, (6) stem pubescence, presence or absence and type, (7) length and width of loment joints, (8) nature of dorsal and ventral margins of loment joints.

The length and width of a typical terminal leaflet, on a leaf approximately one-half the distance between base of plant and inflorescence, was determined for each specimen.² Leaflet proportions were calculated by determining the ratio length-width, and are tabulated in figure 1. The most obvious feature

² Preliminary determinations were made in which several leaflets on each specimen were measured, the proportions length-width calculated and averaged for each. It was found that while linear length and width were subject to some variation, the leaflet proportions (for blades from middle portion of stem) were quite constant—for the broader-leaved specimens frequently consistent to the second decimal place. Subsequent determinations were made on basis of a single leaflet on each specimen.

of the data is the diverse nature of the leaflets which range from about 1.5 to 8-10 times as long as broad. The curve is essentially unimodal, and does not suggest any simple manner in which the specimens could be grouped into two categories on the basis of leaflet proportions.

Leaf pubescence is abundant or sparse, somewhat spreading or strigose. Pubescence is more evident on the lower surface of the leaves than the upper. Glabrate or scantily hairy forms tend to have appressed hairs. Uncinate trichomes are commonly present along the main veins, particularly near base of blade (more often on upper than lower surface). As the leaves age, a considerable portion of the pubescence is lost.

Since degree of pubescence is used as a basis for distinction between *D. paniculatum* and related species, an attempt was made to evaluate the character on a quantitative basis. However, because of loss or destruction of hairs, strictly comparable observations may not have been possible. *A priori*, then, the practical taxonomic value of pubescence variation may be questionable.

Density of pubescence on the lower surface of the leaves was tabulated as follows:³

Approximate distance between adjacent trichomes in terms of length of the hairs.

| | Code no. |
|---------------------------|----------|
| 1/4 length of hairs | 1 |
| 1/2 length of hairs | 2 |
| 1 length of hairs | 3 |
| 2 length of hairs | 4 |
| 4 length of hairs | 5 |
| 8 length of hairs | 6 |

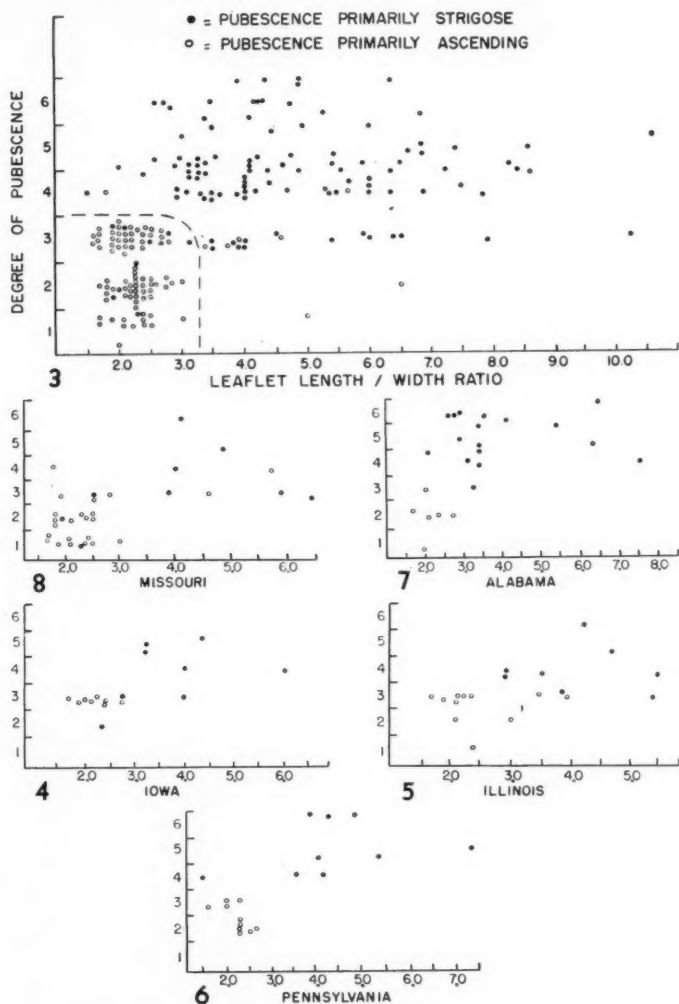
The data is tabulated in figure 2. Leaflet proportions and pubescence are considered simultaneously in figure 3; this scatter diagram also includes observations on the character of the pubescence, i.e., whether strigose or spreading. It is to be noted that nature of pubescence is to some extent correlated with leaflet length-width ratio and amount of pubescence.

As regards stem pubescence, stems of plants of the *D. paniculatum* type (e.g., narrower leaflets, scant leaf pubescence) are generally glabrate; pubescence, if present, is most frequently in the form of uncinate hairs. Specimens tending towards the *D. dillenii* extreme (broader, hairy leaflets) more frequently have hairy stems with villous, or villous and hooked trichomes. It was not possible to make a quantitative determination of this pubescence.

Petiole length was determined on a median blade, halfway between base of plant and inflorescence, for each specimen. A tabulation of the figures resulted in approximately a normal distribution with extremes of 0.4 and 4.8 cm. It is possible, because of petiole variation on a single plant, that all measurements were not equivalent.

Species within the *Desmodium paniculatum* group are said to differ in degree of persistence of the stipules. These structures were completely absent

³ This procedure was followed rather than that of counting hairs on a given unit area of the leaflet because determinations could be made more quickly. The trichomes are relatively consistent in length, hence figures are comparable. Observations were made, insofar as possible, on mature leaves which appeared still to have retained their full complement of pubescence.



Figs. 3-8. *Desmodium paniculatum* complex. Variation in leaflet proportions and pubescence.—3. Based on all specimens (202) examined. 4-8. Based on specimens from specific states.

on many specimens examined; on others, they were present at some or most of the upper nodes. The time of collection (of the specimen) appeared to have a definite influence on the evidence of stipules and a classification in terms of degree of persistence did not appear practical.

Thickness and degree of reticulation of the blades is said to differ widely between various species of the series *Stipitata*. Specimens of the *D. paniculatum* complex examined differed to some extent in regard to these characters, but no precise procedure for determining or cataloguing slight differences could be devised. Some of the narrow-leaved *D. paniculatum* extremes possibly possess the most reticulate blades, but, in general, there appears to be little correlation between the *D. paniculatum* and *dillenii* type plants and either reticulation or blade thickness. Certainly, ecological as well as genetical factors affect the relative thickness of the leaf blade, and further, the appearance of this characteristic on herbarium sheets is influenced by the processing of specimens preparatory to mounting.

One hundred seventy-four of the specimens studied possessed loment. Measurements were made of the length and width of a typical medial segment on each plant. The length was found to be quite variable, measurements ranging from extremes of 4 to 9 mm. This variability, was unimodal with 48 determinations falling at the mode of 6 mm. A greater proportion of the measurements fell between 5 and 6 mm. than between 6 and 7 mm. Width of the loment joints varied between 3 and 5 mm. The distribution was unimodal; nearly half the measurements were at the mode of 4 mm. Distribution of the ratio of the length to the width of the loment joints was likewise unimodal. Leaflet proportions and loment segment length were plotted jointly but there was no observable correlation between the two sets of observations.

Loment segment shape is relatively consistent in the *Desmodium paniculatum* complex. However, the upper suture may be slightly angled, rounded, or nearly straight. The lower suture, on completely mature segments, usually appears angled but intergrades into a more rounded form. Degree of maturity affects the shape of the segments to the extent that the entire range of variability was frequently observed on a single specimen, and contiguous segments of the same loment would occasionally fall into different categories. Attempts to catalogue this character were abandoned.

The above data was studied in the light of collection locality to determine if certain plant types might be geographically restricted. Since leaflet proportions and pubescence have been widely employed in segregating the *D. paniculatum* and *dillenii* types, some of the geographical data pertaining to these forms is presented in figures 3-9. The larger scatter-diagram, figure 3, as we have seen, represents the variability of all specimens examined; the surrounding inserts portray individual states from which the larger number of specimens were available.⁴ The individual states appear to possess essentially the same

⁴ The author is aware that, as a geographical analysis of variability, the above procedure is somewhat generalized. However, if well-marked geographical entities were present, tentative evidence of their existence should be obtainable by these methods. In such an event, the characteristics of the entities could subsequently be subjected to closer examination through employment of more precise procedures.

type of variability as the complex as a whole, and all include representatives of the various phenotypic extremes. Perhaps the most significant deviation from the typical pattern is represented on the Alabama chart. In this state, a higher proportion of the broad-leaved, scantily pubescent forms are present in comparison to other areas recorded.

Figure 9 compares averages, pubescence and leaflet proportions, for each state with the overall mean. The wide disparity between states is obvious, but the distribution appears random. The averages for several of the states are based on relatively few specimens.

Discussion.—Most botanists distinguish *Desmodium paniculatum* and *D. dillenii* primarily on the basis of differential leaflet proportions and pubescence. The usual (or possibly average) dividing line may be approximately as plotted in figure 3, but individual interpretations, as indicated both by manual treatment and herbarium sheet identifications, are subject to considerable variation. A satisfactory separation of these species does not appear feasible on the basis of leaflet proportions or any of the other characters studied (i.e., loment size, shape, thickness of blade et al.).

Schubert (1950) has segregated the elements usually attributed to *D. dillenii* Darl. into two species—*D. perplexum* Schub. with acute leaflets, long petioles, thinner leaflets, and *D. glabellum* (Michx.) DC. with obtuse, usually retuse leaflets, shorter petioles and thicker leaves. The present author was unable, in some instances, to catalogue or accurately measure the type of variability in question (e.g., in regard to thickness or apical curvature of leaflets), and found no character or combination of characters which would render consistent identification of these two groups feasible.

Other varieties or species which have been segregated from *Desmodium paniculatum* seem to have little significance except as a means of designating extremes.

Considering the complex as a whole, a wide range of variability is evident in the shape and pubescence of the leaflets, and pubescence of the stem. The loment is relatively consistent in shape. The size of the loment is variable but this variation is unimodal and apparently in large part correlated with degree of maturity.⁵ Leaflet shape and pubescence are interrelated but there is little or no correlation between vegetative and fruit structure; numerous phenotypes include all possible combinations of these characters. All or nearly all of the phenotypes appear to occur throughout the total range of the complex. There is some evidence that population modes may differ but the number of specimens examined is too small to draw valid conclusions; likewise, the degree of homogeneity of populations may be subject to geographical variation. A proper elucidation of the relationship between the numerous phenotypic forms within this group will probably require population analyses in different parts of the country.

Taxonomic conclusions.—The data presented does not support the thesis that the *Desmodium paniculatum* complex can be separated into 2 or 3 mutually exclusive units; with present information it appears more realistic to con-

⁵ Two of the specimens examined, possessing large loment, showed evidence of hybridization with *D. cuspidatum* (Willd.) Loud.

sider it as a single species. So that nomenclatural recognition of the more conspicuous phenotypes may be possible two form (not geographical) varieties are recognized. These varieties, which are roughly equivalent to the *Desmodium paniculatum* and *D. dillenii* of most American literature, may be approximately differentiated following the grouping in figure 3, i.e., broad-leaved plants with abundant, spreading pubescence, var. *dillenii* (see below)—all others, the typical variety.

In regard to nomenclature, the typical form of *Desmodium paniculatum* is the narrow-leaved phase (Schubert, 1950)—which is then, var. *paniculatum*.⁶ Schubert rejected *Desmodium dillenii* Darl. as a *nomen confusum* on the basis that Darlington's material contained two discordant elements. Since the present study regards those elements as largely composing the same complex, there is no barrier to the use of the epithet, and it is employed to represent the pubescent phase of the species. *Desmodium glabellum* (Michx.) DC. is assigned to typical *D. paniculatum* (but as employed by various authors falls under var. *dillenii*). *M. paniculata* var. *obtusata* (Desv.) Schindl., not identifiable except for synonyms cited, overlaps both vars. *dillenii* and *paniculatum*.

A summary of categories follows:

DESMODIUM PANICULATUM L.

Characters of series *Stipitata* Schubert (1950). Plants ascending to spreading, frequently much branched at base. Leaves variable as to petiole length and breadth of leaflets, usually weakly reticulate. Stipules early deciduous or some of them persistent. Leaf pubescence abundant or scanty, spreading or strigose, mostly of a hirsute type; hooked trichomes commonly present along main veins. Stems pubescent or glabrate, most frequently of intermingled spreading and hooked hairs. Loment segments mostly 5-6 mm. long (extremes 4-8 mm.), 4 mm. wide (extremes 3-5 mm.); lower suture usually obtusely angled, the upper curved or slightly angled. Species widely distributed throughout the eastern United States, west to central Texas and Nebraska.

A variable complex containing numerous intergradient forms, of which the following are more clearly distinguishable.

DESMODIUM PANICULATUM (L.) DC. var. PANICULATUM—*Hedysarum paniculatum* L. Sp. Pl. 749. 1753. *Desmodium paniculatum* (L.) DC. Prod. 2:329. 1825. *D. glabellum* (Michx.) DC. Ibid. 329. 1825. *D. paniculatum* var. *angustifolium* T. & G. Fl. N. Amer. 364. 1840. *Meibomia angustifolia* (T. & G.) Kearney Bull. Torrey Club. 2:481. 1893. *M. chapmani* (Britt.) Small Man. Southeast. Fl. 734. 1933. *M. paniculata* var. *obtusata* (Desv.) Schindl. Repert. Spec. 22:282. 1926, in part. *Desmodium paniculatum* var. *typicum* Schub. Rhodora 52:152. 1950.

Terminal leaflets usually 3-8 times longer than wide, sometimes broader. Leaflet pubescence moderate to scant, commonly appressed, most distinct on lower surface; distance between hairs usually equaling or exceeding length of

⁶ This follows procedure determined at the 1950 Botanical congress. The revised Rules of Nomenclature have not yet been published (as of this writing, May, 1951).

trichomes. Stems glabrate or sparsely pubescent, most of hairs hooked. Extending throughout total range of species.

DESMODIUM PANICULATUM var. DILLENII (Darl.) Isely, comb. nov. *D. dillenii* Darl. Fl. Cestr. 414. 1837. *D. glabellum* of authors, in part, not (Michx.) DC. *D. perplexum* Schub. Rhodora 52:154. 1950, in part. Probably *D. paniculatum* var. *pubens* of authors, in part. *M. paniculata* var. *obtusata* (Desv.) Schindl. Repert. Spec. 22:282. 1926, in part.

Terminal leaflets mostly 1.5-3.0 times as long as wide. Lower surface of leaflets pubescent, predominantly with spreading trichomes. Stems pubescent, usually with a mixture of hooked and spreading hairs.

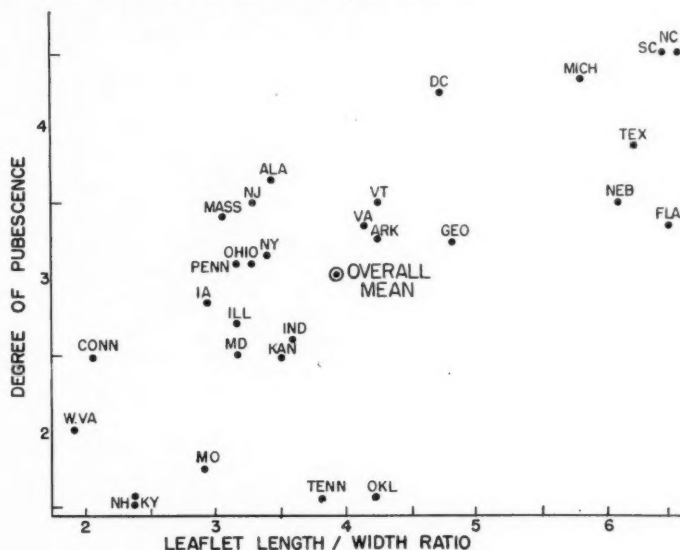


Fig. 9.—*Desmodium paniculatum* complex. Variation in leaflet proportions and pubescence. Average by states and overall mean.

DESMODIUM VIRIDIFLORUM COMPLEX

Desmodium viridiflorum (L.) DC. has long been distinguished from related species on the basis of its densely pubescent leaflets, its semi-persistent, hairy and frequently reddish stipules, and pubescent bracts. Although variable with respect to a number of characters—a fact which was recognized by Torrey and Gray (1840) who felt that two or more species might possibly be confounded under the same name—no varietal or specific subdivisions of the complex were recognized until Schindler (1926a),⁷ described *Meibomia nut-*

⁷ Cited as 1927 by several authors on basis of volume date. However, the issue in which Schindler's article appears bears the caption, December 10, 1926.

tallii, distinguishing it from *M. viridiflora* primarily on the basis of shape of the loment segments. Schubert (1950) reiterated Schindler's conclusions, distinguishing the two species on the following basis: *Desmodium viridiflorum* (L.) DC. Loment segments chiefly rhomboidal, angled above; terminal leaflets generally two-thirds as wide as long, mostly rhombic to deltoid in shape. Plants averaging larger (both in stature and in individual parts) than the following, primarily of coastal plain occurrence. *D. nuttallii* (Schindl.) Schub. Loment segments rounded above; terminal leaflets generally about one-half as wide as long, elliptic-ovate in shape. Plants averaging smaller than above, more widely distributed inland. Schubert also pointed out that the widely employed combination *Desmodium viridiflorum* (L.) Beck (Bot. 84. 1833) is antedated by *D. viridiflorum* (L.) DC. (Prod. 2:329. 1825).

The object of the following studies was to obtain further information in regard to the specific identity of *Desmodium nuttallii*. Eighty-five specimens were available for observation of which thirty-six possessed fruits sufficiently mature for appropriate determination.⁸

Observations.—Employing methods described under *Desmodium paniculatum*, leaflet length, width, and proportions were determined for each specimen. The data upon tabulation revealed a unimodal distribution in regard to both leaflet size and proportions with modes at 7 cm. (length) and 1.5 (length/width) respectively. These data are plotted in scatter-diagram form in figure 10. Observations were also made on leaflet shape which varied from ovate-deltoid (broadest towards base) to elliptic (broadest at middle), but no correlation with other characters could be established.

Length of loment segments ranges from 3.0-8.5 mm., with a mode between 5-6 mm. The width varies from 2.5-5.0 mm., most segments falling in the range 3-4 mm. Length and width are correlated, i.e., larger loment segments were wider, but no sharp grouping into two size classifications is evident. Loment length is tabulated against leaflet length-width ratio in figure 11. While there is no convenient cleavage into two groups there is a tendency for the plants with broader leaflets to have larger pods and *vice versa*. No such correlation of variable vegetative and loment characters was observed among elements making up the *Desmodium paniculatum* complex.

Tabulation of loment segment shape in terms of the angling or rounding of the sutures was carried out as follows. The upper suture was considered to be angled (a), rounded (r), intergradient (a-r), or nearly straight (s); the lower suture was rounded, angled, or intergradient. The various combinations tabulated were arranged in linear sequence, and given numerical indices from 1 (rounded) to 3 (angled), viz.:

⁸ A greater proportion of the total number of specimens examined were in fruit but the loment segments were not fully mature. Since degree of maturity affects size and shape of the segments it was deemed best to restrict measurement determinations to those completely mature even though it meant a considerable reduction in actual number of specimens studied.

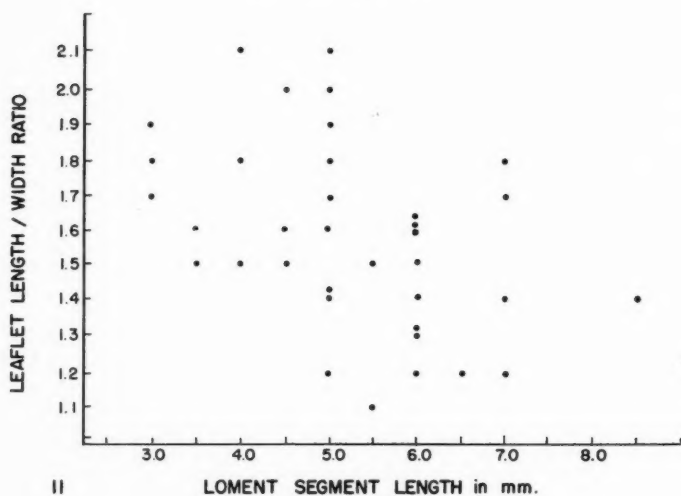
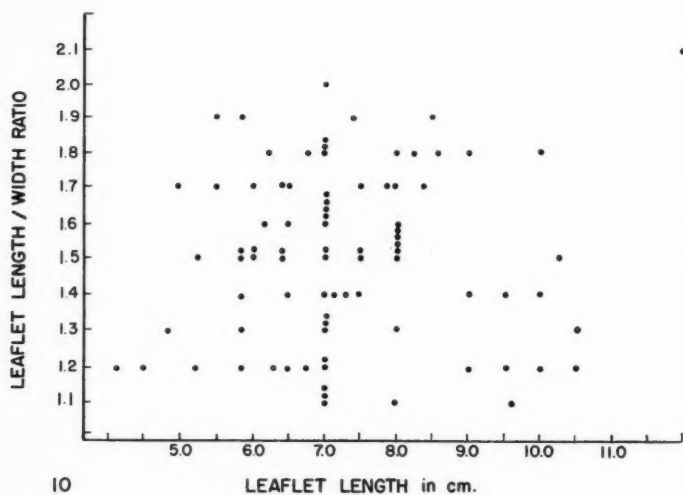
| Loment Type | Character Combinations (numerator refers to upper suture; denominator to lower) | Numerical Assignment |
|--------------------------------------|---|-------------------------|
| Rounded | r — r | 1 |
| Rounded, one suture intergradient | a-r r s-r — — — r a-r r | 1.5 |
| Sutures unlike | a r s s — — — — r a a r | 2 |
| Angled, one suture intergradient | a-r a s-r — — — a a-r a | 2.5 |
| Angled | a — a | 3 |

Figure 12 in which loment shape is tabulated against loment length indicates: (1) a moderate degree of divergence of two loment shapes—i.e., if those with numerical indices of 1 and 1.5 were considered the *nuttallii* type and those, 2.5 and 3, to be the *viridiflorum* form, only one specimen (with a value of 2) would be undetermined, (2) considerable correlation between segment shape and length, the longer segment types usually being those which were angled.

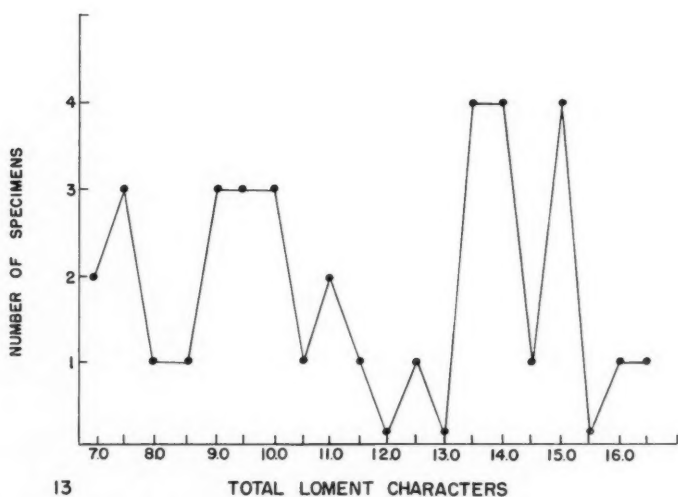
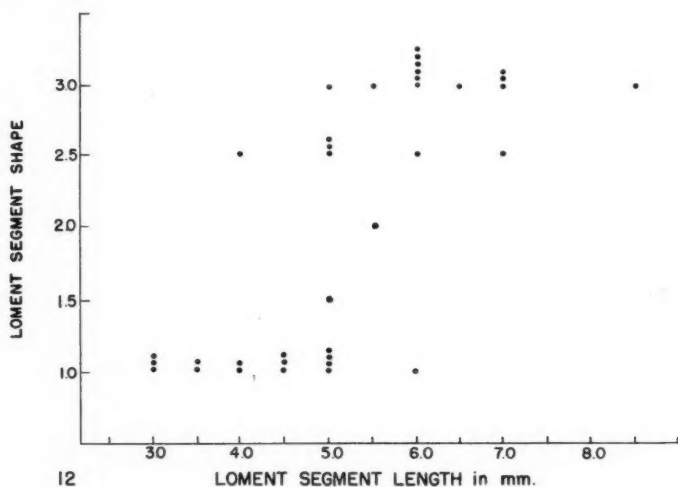
Various loment characters were considered jointly by summing figures obtained as follows: (1) length of loment segments in mm., (2) shape of segments, determined as above indicated, (3) number of segments, 3, 4 or 5, (4) curvature of loment as a whole, 1 representing straight, and 0, dorsally curved. The totals, figure 13, are to some extent, bimodally deployed, the group at the left hand side of the chart representing the *nuttallii* type and the right, the *viridiflorum* form. The sample size is somewhat too small to allow entirely satisfactory conclusions.

Total loment characters and leaflet ratio are plotted jointly in figure 14; the name of the state in which each specimen was collected is appended. The majority of the specimens fall into two fairly distinct groups which are characterized by differences in both loment characters and leaflet ratio, although there is considerable overlapping in regard to the latter character. As to the geographical characteristics of the components of these groups, the *viridiflorum* unit (right side of figure) appears to be southern and coastal (as previously noted by Schubert, 1950) while members of the *nuttallii* complex extend further to the north and a greater proportion are inland.

Discussion.—The data presented indicates that the *Desmodium viridiflorum* complex contains two sub-units possessing, in various degrees, differential loment, leaflet, and geographical characteristics, and the author concurs with



Figs. 10-11. *Desmodium viridiflorum* complex.—10. Variation in leaflet proportions and length. 11. Variation in leaflet proportions and loment segment length.



Figs. 12-13. *Desmodium viridiflorum* complex.—12. Variation in loment segment length and shape. 13. Variation in total loment characters.

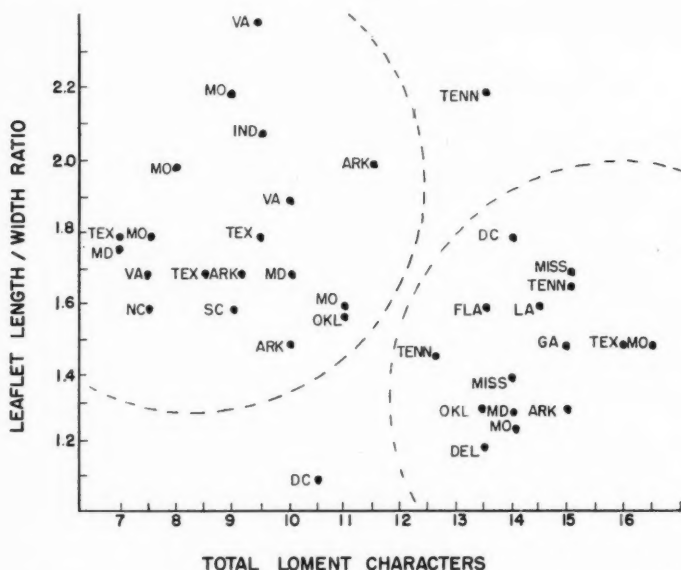


Fig. 14.—*Desmodium viridiflorum* complex. Distribution, and variation in total loment characters and leaflet proportions. Dotted lines enclose those portions of chart which can be assigned to *D. nuttallii* (left) and *D. viridiflorum* (right).

Schubert, and with Schindler in recognizing two species. This decision is not entirely satisfactory (possibly the same can be said of any taxonomic judgment involving intergradient categories), but is given considerable weight by the presence of two loment types which are largely distinguishable; further, that there is some degree of correlation between loment characters, leaflet measurements and distribution of the plants involved.

Both Schubert and Schindler emphasize shape of mature loment segments in distinguishing these species. More accurate diagnoses, however, can be made if due consideration is also given to the size and number of segments, as well as the curvature of the pod. Collections lacking mature fruit cannot always be given more than a tentative identification. The leaflets average considerably the broader in *D. viridiflorum*; if the blades are 1.1-1.4 times as long as broad, the specimen is fairly certain to be that species. If the leaflets are 1.7-2.4 times as long as broad, the plant is probably *D. nuttallii*. However, blades of the majority of specimens of both species fall in the overlap area of 1.4-1.7 and cannot be distinguished on the basis of this character. While leaflet size is likewise somewhat diagnostic, the proportion of overlapping is even larger. The collection area may frequently indicate the probable identity of doubtful specimens.

Taxonomic conclusions.—Differential characters of the two species are summarized below. A nomenclatural summary is not included since this has been presented by Schubert (1950) and no questions involving nomenclature were concerned in the present study.

Desmodium viridiflorum (L.) DC. Prod. 2:329. 1825.—Terminal leaflets usually 1.1-1.7 times as long as wide, tending to be broader at base, 3-10 cm. in length, a greater proportion of them exceeding 6 cm. than in following species. Loments straight or nearly so; segments 4-5 in number, usually 5-7 (8) mm. in length; 3.5 (3.0)-4.0 mm. in width, obtusely angled beneath, angled, nearly straight or somewhat rounded above. Plants extending north to Oklahoma, Tennessee and Maryland, apparently less common in interior than the following.

Desmodium nuttallii (Schindl.) Schub. Rhodora 52:142. 1950.—Terminal leaflets 1.4-2.4 times as long as wide, usually widest about middle, 3-9 cm. in length, the majority not exceeding 6 cm. Loments usually curved longitudinally (dorsal margin convex); segments 3-4 in number, mostly 3.5-5.0 mm. in length; 3.0 (2.5)-3.5 (4.0) mm. in width, most frequently rounded above and below, but sometimes somewhat angled. Plants ranging north to Indiana, apparently more frequently in the central U. S. than above species.

SUMMARY

Representatives of the *Desmodium paniculatum* complex are considered to constitute a single, polymorphic species, *D. paniculatum* (L.) DC. The two most common phenotype-groups are characterized as varieties.

The *Desmodium viridiflorum* complex is considered to be represented by two species, *D. viridiflorum* (L.) DC. and *D. nuttallii* (Schindl.) Schub.

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Notes and Discussion

The Nieuwland Herbarium of the University of Notre Dame. A Report for the Period 1947-1952. I.

A considerable number of new plant accessions were added to the Nieuwland Herbarium during 1947-1952. In addition to more than 10,000 sheets received as exchanges, 20,000 specimens were acquired by purchase, gifts, or purchase-exchange arrangements through THE AMERICAN MIDLAND NATURALIST, from private collectors, and authors. Thus the actual number of plants received exceeded the number of specimens mounted and integrated in the Herbarium during this period. Prior to 1947, there were an estimated 25-30,000 unmounted sheets which were not integrated into the Nieuwland Herbarium. In the last $3\frac{1}{2}$ years, more than 29,000 specimens of vascular plants have been mounted and deposited in this herbarium. These came from old unmounted collections (on hand) and from recent accessions.

Among the many collections received, some particularly deserve mention. These are: the Wiggins and Reed *Flora of the Sonoran Desert*; exchanges from the Smithsonian Institution, the University of California at Davis, Calif.; a contribution toward a *Flora of Antioquia* from the Universidad Nacional, Medellín, Colombia, S. A., collected by F. A. Barkley, Albert L. Delisle, et al.; and a representative collection of Argentina (Tucumán University) by F. A. Barkley. Some rather large accessions including plants of Texas and adjacent Mexico were made by B. C. Tharp and F. A. Barkley from the U. of Texas. Grateful acknowledgement is made for the receipt of many sheets from The National Herbarium of Victoria, Melbourne, Australia, and the W. J. Eyerdam collection of the Mosses of Alaska as well as for the William Bridge Cook's excellent Mycobiota of North America.

The largest single accession was that of an excellent collection (exceeding 5,000 sheets) purchased from Dr. John E. Potzger of Butler University. This collection consists mainly of grasses of Indiana but also includes other general collections from Michigan. With this substantial addition to the already large representation of grasses collected by the late Rev. Julius A. Nieuwland, C.S.C., the Herbarium justly boasts a superb collection, which is representative of the entire state of Indiana but with particular emphasis on the northern tiers of counties.

Significant additions to the sedges were made to the private collection by Rev. Peter E. Hebert, C.S.C. The Hebert Collection, noteworthy for its general excellence, represents the largest private collection in the Nieuwland Herbarium (outside of the Greene Herbarium of more than 100,000 plants). His entire herbarium consisting mainly of plants from Berrien Co., Mich., and St. Joseph Co., Ind., comprises more than 5,000 sheets (conservative estimate). More than 1,000 species are represented from Berrien County, thus constituting a very illustrative flora of that Michigan county.

The most serious problems encountered have been those of space and storage. The need for storage cabinets has been the more constant and pressing one. As a partial solution, the preparation room has been utilized as an extension to the Herbarium, thus partially solving the need for expansion in the immediate future. Since 1949, the number of storage cabinets has been substantially increased by the purchase of 18 additional ones. The present supply falls far short of our needs but previous congestion caused by the integration of the backlog of several thousand plants has been lessened. Future plans envisage the purchase of two cabinets annually, which in time should do much to solve the storage problem.

The original storage cases in the Herbarium were constructed locally of wood with a sheet metal covering and have served adequately for over 25 years. Serious objections to these are that they are neither fire-proof nor dust-proof, both factors which seriously reduce their usefulness. All new cabinets are of standardized, dust-proof, steel-welded design. Each measures $30\frac{1}{4}$ " x $19\frac{1}{8}$ " x $83\frac{13}{16}$ " (overall), has one door and contains

26 compartments of conventional size, in two tiers. The door has a three point latching device and closes against an insect- and dust-proof packing of sponge rubber, $\frac{3}{4}$ " wide and $\frac{1}{4}$ " thick.

The cabinets have been eminently satisfactory. However, it would be a distinct advantage to incorporate in each, at waist height, a retractable or sliding shelf to facilitate examination of specimens, without the necessity of removing them elsewhere for routine study.

Numerous loans of sheets were made to other institutions from the Nieuwland Herbarium during the past four years. Such loans were extended to specialists and/or graduate students working toward advanced degrees for use in the preparation of taxonomic keys or in the revision of genera or specialized groups of plants. During the past four years the Herbarium was honored by the presence of several eminent botanists who visited either the Greene or the Nieuwland Herbarium with regard to taxonomic research problems or concerning the local flora.

It should be mentioned that since the specimens in the Greene Herbarium cannot be loaned, the Herbarium provides a photographic service which has now been in operation since 1948 and has handled an average of two or three requests per month. Photographs of type specimens have now been sent to several institutions, mostly from the southwest or west, the area from which the plants in the Greene Herbarium are most representative.

Experimental work on the cytogenetics and the polymorphy of certain *Asters* in northern Indiana, presently in preparation or already in press, has been substantially assisted by reference to the large collections of this genus in the Herbarium. Experimental research on tetraploidy in the genus *Aster* just completed, served to emphasize the joint role which the Herbarium and a modern experimental greenhouse can and do play in plant breeding and cytogenetics. Grateful acknowledgement, therefore, is made to the foresightedness of the administrative officers of the University of Notre Dame, for providing and maintaining these facilities.—A. L. DELISLE, Curator, Notre Dame, Indiana.

Oxycoccus as a Genus

In proposing a new combination, it is advisable to restate the reasons for so doing. Not only at a casual glance, but in some fairly fundamental characters, the blueberries and cranberries belong in different groups. Following a number of others, I advocate recognizing them as separate genera. This means using the generic name *Oxycoccus* for cranberries, which was first proposed as a genus by Tournefort ex Adanson in 1763.¹

For comparison, *Maianthemum* is maintained as a separate genus from *Smilacina* because it is 4-merous. In the cranberries, not only are the flowers 4-merous, but also the petals are united only at the base and the lobes are many times the length of the tube. In contrast, in the blueberries, the corolla is united nearly its entire length and only slightly lobed at the summit. The long terminal tubes of the anthers in the cranberries, while less fundamental, contributes to the differences between the cranberries and the blueberries.

For these reasons, I wish to maintain *Oxycoccus* Tourn. as a genus and need to use the combination *Oxycoccus palustris* Pers., var. *ovalifolius* (Michx.) n. comb. which so far as I can ascertain has not been published previously. This variety was first published as *Vaccinium Oxycoccus* L., var. *ovalifolia* Michx. It seems to be the most common cranberry in Wisconsin and certainly is such in Lincoln County, Wisconsin.

For the same reasons as given above, the species sometimes treated as *Vaccinium erythrocarpum* Michx. seems to me to belong with the cranberries in the genus *Oxycoccus* as was also the opinion of Persoon who first made the transfer.²

To meet the objections which are sure to be raised, I refer to Gray's *Manual*, ed. 8, p. 1135, where it is stated under *Vaccinium erythrocarpum* Michx.: "Closely related species in e. Asia; worthy the thought of those who separate subgen. *Oxycoccus* as a genus!" This is a familiar and frequent situation.

¹ Dalla Torre & Harms.

² Pers. Syn. 1: 419 (1805).

The Pyrolaceae and Ericaceae, which are sometimes put in separate families present transitional forms. Aside from vegetative characters such as shrubs or herbs, and the presence or absence of chlorophyll, which are not generally the bases for family distinctions, in both families the corollas may consist either of united or distinct petals. In the Ericaceae, the seed-coat may be loose or close; the fruit may be 2-10-locular, either a capsule or a drupe; free from the calyx or united with it. In the Pyrolaceae, the seed-coat is loose; the fruit is a capsule, free from the calyx; the fruit is 4-5-locular. If, in spite of all these points of transition between the two groups, they may be treated as two families rather than as one, transitional species between the blueberries and the cranberries ought not to prevent their being treated in separate genera.

It is difficult to establish rules which will settle such a question. It is, and apparently always must be somewhat a matter of judgment and opinion.—FRANK C. SEYMOUR, Tomahawk, Wisconsin.

BOOK REVIEWS

ILLUSTRATED GUIDE TO TREES AND SHRUBS. By Arthur Harmount Graves. Published by the author, Wallingford, Conn. 1952. x+240 pp., illus. \$4.00.

Prof. Graves is Curator Emeritus of the Brooklyn Botanic Garden and Consulting Pathologist of the Connecticut Agricultural Experiment Station at New Haven, and was formerly an Instructor in Forest Botany at the Yale University School of Forestry, Assistant Professor of Botany at Yale, and is still a Collaborator in the Division of Forest Pathology of the U. S. Department of Agriculture. The primary purpose of this book is indicated as a help to the property owner of the Northeastern States (defined as New England, New York, New Jersey, Pennsylvania, and Delaware) to recognize his woody plants, whether native or cultivated, including trees, shrubs, and woody vines. The keys are designed for both summer and winter use. The descriptions of genera and species are purposely short, the reader being referred to the manuals for fuller diagnoses. The excellent and copious illustrations are from original drawings by Miss Maud H. Purdy, formerly of the Brooklyn Botanic Garden, based on living material collected by the author. Prof. Graves has followed Standardized Plant Names in much of his common nomenclature as well as in lower-casing all specific names and using only one *i* in genitives of Latin patronymics. An unusual feature is the chapter "Short Cuts to Naming" (pp. 214-221), with keys to buds, bark characters, coloring, spines and prickles, aromatic odors, etc. There is a glossary, a bibliography of 52 titles, and an index. This is one of the best available books of its kind, and unique in some respects.—W. A. DAYTON, U. S. Forest Service, Washington, D. C.

HANDBOOK OF NORTH DAKOTA PLANTS. By Orin Alva Stevens. North Dakota Agricultural College, Fargo. 1950. 324 pp., 319 figs. \$4.50.

This book is intended to present in a useful form an account of the vascular plants growing spontaneously in North Dakota. It is the first publication of the North Dakota Institute for Regional Studies, established in March, 1950, for scientific study of botanical, zoological, and geological resources of North Dakota.

As North Dakota is near the center of the North American continent in the grass-land area of the northern part of the Great Plains just beyond the edge of the eastern deciduous forest, there is consequently, little diversity of vegetation. Wooded areas are rare, occurring chiefly along the water courses, and in the Turtle Mountains, a series of low hills in the northern part of the state. The chief trees are *Populus tremuloides* and *P. balsamifera*. The effect of agriculture has been to reduce much of the original prairie to farm land.

The introductory pages of Dr. Stevens' book contain a brief account of plant collections in North Dakota from the time of Lewis & Clark in 1806, an account of physiography in relation to plant distribution, a short discussion of the distribution of species within the state, and some directions for the use of keys. There is a short key to the principal plant families, and a general key to families and genera.

This book, which is slightly beyond the orbit of *Gray's Manual*, both geographically and taxonomically, includes 1143 species. These are keyed and briefly described. The total number of families is 102. Compositae is largest with 155 species. Grasses comprise 145 species, and legumes 68. There are 19 "ferns and fern-allies," and 5 gymnosperms. About 15 per cent of the species treated in the book are not native to North Dakota. The taxonomy appears to be sound and practical, and seems to be based largely upon personal study of local plants. There are, however, a few technical points here and there that might be worth re-investigating, as for example, the maintenance of both *Equisetum kansanum* and *E. laevigatum*. The statement, "The snowberry, often planted for its large white fruits is a form of the same species," i.e., *Symphoricarpos albus*, leaves out of consideration a recent study of this genus, in which these two shrubs have been shown to belong to different species, each with a different geographical area. We are pleased to observe, however, that "pennsylvanica" still has two n's in its first syllable, and that specific names are uniformly decapitalized. This manual is a practical guide for identification of the higher plants of North Dakota, as well as a contribution to our scientific information of the botany of that area.—GEORGE NEVILLE JONES, University of Illinois, Urbana.

ON THE ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION. By Charles Darwin. Philosophical Library, Inc. New York. 1951. xx+426 pp. \$3.75

This is a reprint of the first edition with no changes being made other than in punctuation. The foreword by Dr. C. D. Darlington aptly explains the purpose for this reprint in these words: "This edition has never been reprinted before. The innumerable translations into other languages have all been made from the later, the longer, and (as it now appears) looser editions which followed it. It should help us in dealing with the problems of rescuing Darwin from ignorant neglect and in protecting him from corrupt adulation. Here is the book as he first presented it to the world. Here is his theory, *unspoilt by later hesitation, unimpaired by yielding to the trivial and captious critic.*" (Italics mine)

The foreword also gives a brief history of the development of Darwin's ideas, the impact of these ideas upon the world of his and later times, and the fate of the ideas in different spheres of influence.—R. L. LIVEZEY, University of Notre Dame, Notre Dame, Indiana.

HINDEASTREA DISCOIDEA WHITE FROM THE EAGLE FORD SHALE, DALLAS COUNTY, TEXAS. By Bob F. Perkins. AN ANNOTATED BIBLIOGRAPHY OF NORTH AMERICAN UPPER CRETACEOUS CORALS. By Bob F. Perkins. THE WOODBINE AND ADJACENT STRATA OF THE WACO AREA OF CENTRAL TEXAS. Edited by F. E. Lozo assisted by Bob F. Perkins. Southern Methodist University, Dallas, Texas. 1951. 11, 44 and 161 pp. \$1.50, \$2.50 and \$7.50.

These three publications form Numbers 2-4 of the Fondren Science Series, begun in 1949 with publication of S. P. Welles' paper on *A New Elasmosaur from the Eagle Ford Shale of Texas* and continued in E. W. Shuler's study of *The Elasmosaur and its Environment*.

The nature of Dr. Perkins' contributions is adequately indicated by their titles; his bibliography of upper Cretaceous corals meets a long-standing need. *The Woodbine and Adjacent Strata* is a symposium designed as a handbook for the 1951 field trip of the East Texas Geological Society. It begins with a paper on the climatic history of the Grand Prairies of Texas, through which the field trip passed. Other chapters deal with the history and development of Woodbine oil fields, with the South Bosque field, the geology of two reservoir areas, and related subjects. J. N. Monroe discusses sandstone dikes in the Woodbine, and W. S. Adkins and F. E. Lozo contribute a paper (the longest in the book) on the stratigraphy of the Woodbine and Eagle Ford formations in the Waco area, with six plates illustrating fossils. There are 35 folded maps and sections, which explain the book's relatively high price.

Tipped in as a frontispiece is a portrait of Helen Jeanne Plummer (1891-1951), a

frequent contributor to this journal during the 1930's who also served as editorial consultant for papers on micropaleontology. In format, printing and binding the book is a credit to its publisher and to the forty-eight companies and persons who contributed to the fund which made it possible.—CARROLL LANE FENTON, 404 Livingston Ave., New Brunswick, N. J.

DESTRUCTIVE AND USEFUL INSECTS: THEIR HABITS AND CONTROL (Third edition).

By C. L. Metcalf and W. P. Flint, revised by R. L. Metcalf. McGraw-Hill Book Co., New York. 1951. 1071 pp., 584 illus. \$10.00.

The wide usefulness attained by the two previous editions of this book will assure from all a warm welcome for the appearance of this most recent edition. During the 23 years which have elapsed since the appearance of the first edition in 1928 and of the second edition in 1939, there are few fields of science which have undergone more revolutionary changes than have taken place in economic entomology. Not only have many of the older inorganic insecticides and plant poisons been largely replaced by synthetic organic toxicants of outstanding activity, but new principles of insecticide dispersal and new types of spraying and dusting machinery have made important changes in methods of insect control, and thus brought about the great desirability of thorough down-to-date revision of this long standard reference work.

In the preparation of this new revision every care has been taken to preserve not only the original format but also the style of presentation, and while much has been added, very little has been removed. Some idea of the scope and general arrangement of the book may be gained by a brief survey of its contents: In addition to prefaces to the first and third editions and tables, synopses and outlines, consideration is given to such subjects as Insects as pests of man (pp. 1-42); Value of insects to man (43-76); External morphology of insects (77-95); Internal anatomy and physiology of insects (96-120); Mouthparts of insects (121-146); Development and metamorphosis (147-169); Place of insects in the animal kingdom (170-185); Orders of insects (186-254); Insect control (255-359); Apparatus for applying insecticides (360-386); Insects injurious to corn (387-452); Insects injurious to small grains (453-474); Insects injurious to legumes (475-502); Cotton insects (503-516); Tobacco insects (517-525); Insects injurious to vegetable gardens and truck crops (526-620); Insects injurious to deciduous fruits and bush fruits (621-746); Citrus insects (747-762); Insects attacking shade trees and shrubs (763-805); Insect pests of greenhouse plants and flower garden (806-842); Household insects and pests of stored grains, seeds and cereal products (843-897); Insects injurious to domestic animals (898-959); and Insects that attack and annoy man and affect his health (960-1004).

Because of the many, revolutionary and sometimes bewildering advances which have taken place during the past decade, it became necessary as would be expected that a considerable part of the book be almost entirely rewritten. For example: in the chapters on Internal anatomy and physiology of insects there have been incorporated recent discoveries in insect physiology and biochemistry, and new sections have been added on insect nutrition and insect pigments; the tables of plant and animal diseases transmitted by insects have been brought down to date with recent discoveries, and numerous other like changes might be cited. However, as would be obvious, the sections on Insect control and on Apparatus for applying insecticides are those in which most important revisions have been necessary. In these there are included structural formulas and descriptions of the chemical, physical, and insecticidal properties of more than one hundred and fifty substances used in control of insects at the present time. Of course, particular attention is given to the development in recent years of synthetic organic materials, including full and detailed discussion of DDT compounds, and analogues DDD, DEDT and others. The known possibilities as well as limitations of other products such as benzene hexachloride, toxaphene, chlordane, the dinitrophenols, HETP, TEPP, parathion, styrene dibromide and others likewise are discussed fully.

Then too, new sections have been added on activators, attractants, emulsification, wetting, spreading, insecticide formulation, mothproofing, repellents to bloodsucking insects, and insecticide-resistant insects. The sections dealing with biological and legal control have been expanded, and those on apparatus used for applying insecticides have been completely modernized and new illustrations have been provided of latest types of

equipment, while new sections have been added on aerosols, air-atomizing sprayers and aircraft dispersal of insecticides.

It may be noted in general that while the first part of the book gives the fundamentals of technical entomology, the last part has been devoted to an analysis one by one of over five hundred of the more important insect pests of the major crops of the United States and southern Canada arranged according to type of damage performed, thus, it became desirable that control measures for each of these also be revised to incorporate where necessary recent discoveries. The references to the literature at end of each of these discussions likewise have been revised to include citations to latest, most complete informative reviews and Federal and State publications. The scientific and common names of these insects too have been rechecked and have been brought into conformity with the official list of the American Association of Economic Entomologists, and—a most helpful, time-saving feature—trade names of insecticidal products have been appended by footnote whenever essential for clarity. Again, wherever compatible with limitations of space, descriptions of important new insect pests have been added, such as the southwestern corn borer, red-banded leaf roller, citrus bud mite, citrus aphid, yellow scale, vegetable weevil, Pacific mite, Oriental and Mexican fruit flies, dry-wood termites, and various flies and mosquitoes.

Both of the original authors died before the plans for a third edition of this book had become more than fragmentary, and the person who succeeded to the task of revision modestly states in its preface that he has done so largely because of his familiarity with the work and its originators and in having assisted in preparation of the previous editions, and expresses hope that the result would have been acceptable to these men since it represents a memorial to their memory. The entomological fraternity and all others who have used this book have been long indebted to the original authors for its enormous practical helpfulness in their work. They may well be equally grateful for the toil and pains that have gone into its revision.—J. S. WADE, U. S. Department of Agriculture, Washington, D. C.

THE BIRDS OF ROCKY MOUNTAIN NATIONAL PARK. By Fred Mallery Packard. Rocky Mountain Nature Association, Estes Park, Colorado. 1950. 81 pp., map and twelve sketches by Roger Tory Peterson. \$.75.

This little handbook is designed as an introduction to the known bird life of Rocky Mountain National Park and nearby areas. It was written by a qualified observer who as wildlife technician had an excellent opportunity to be constantly in the field. The present list includes all of the birds reported in previous check-lists of the region, and records 219 species, representing an increase of thirty-two over the list published by Park Naturalist H. Raymond Gregg in 1938.

The representation emphasizes the relationship of different species to the geographic life-zones of the park, ranging from the Upper Sonoran and Transition into the Alpine, and points out the need for additional information about the altitudinal distribution of mountain birds. The short descriptions of each species are intended to help park visitors identify the birds they see, but are not complete, and visitors are advised to consult Peterson's *Field Guides* and to have unusual observations verified by park rangers.

This booklet is a welcome addition to the notes on the birds of Colorado, and should encourage people coming to the state to contribute to our ornithological knowledge.—ROBERT J. NIEDRACH.

THREE SPECIES OF PEROMYSCUS. By Thomas T. McCabe and Barbara D. Blanchard. Privately printed: Santa Barbara. 1950. v+136 pp., 32 figs. \$2.00 (from Dr. Barbara D. Blanchard, 1744 Prospect Ave., Santa Barbara, Calif. \$2.08 in California).

It is not unusual for two or more species of the same genus of animals to live in the same geographic region. In such cases it is assumed that differences in habitat or habit prevent destructive competition between the several species concerned, but few actual studies have been made in sufficient detail to demonstrate just what these differences are. The present study gives valuable information about the habitats, growth rate, life histories, and temperaments of three related species of small rodents that live in close association with one another and this aids us in understanding their ecologic interrelations. The

field work was carried out by Thomas T. McCabe, who died before the material could be written up. The laboratory operations, analysis of the data, and writing of the report have been the task of Barbara D. Blanchard.

In the region just east of San Francisco Bay, California, occur the three related species, *Peromyscus maniculatus*, *P. truei*, and *P. californicus*. All three species live along the edges of stands of chaparral, but do not occur in the interior of large and dense stands of this form of vegetation. Not every chaparral edge is inhabited by these mice, but those edge situations with the most abrupt transition to open types of habitat are preferred. There is no clear-cut difference between the three species in their local habitat preferences, but *maniculatus* exists in a wider variety of local conditions and is a more abundant species in the region than either of the other two.

The three species exhibit great differences in habits. *Maniculatus* is almost strictly terrestrial and subterranean in habit. The small burrows made by moles and pocket-gophers are much used as underground runways. These burrows are mostly too small to be entered by either of the other species. *Truei* is an agile climber and jumper and it occurs most frequently in the vicinity of places of refuge, such as is provided by wood-rat houses. *Californicus* is also a climber, but perhaps by reason of its large body size, is less agile than *truei*. *Californicus* makes large bulky nests, in contrast to the smaller and less well-constructed nests made by the other two species. *Truei* and *californicus* prefer habitats with prostrate brush or trees and they tolerate a layer of heavy duff on the ground, while *maniculatus* prefers bare soil.

In temperament *maniculatus* is less easily frightened than either of the two other species, bolder in the presence of danger, and more adaptable. *Californicus* is unaggressive and easily tamed, not easily excited, and inclined to cling to the shelter of its nest. *Truei* differs from the other two species in its high degree of activity and in its seemingly savage and aggressive temperament.

Members of all three species live in established home ranges, but there is little evidence for territorial defense. When strangers of the same species first meet in a small cage, a tumbling "fight" often occurs, but nearly always without damage to either party. When a real fight occurs, however, the large incisor teeth are capable of inflicting serious or fatal injuries. The conclusion that the tumbling "fight" represents real but limited combat without needless injury is undoubtedly correct and the authors deserve credit for emphasizing this point. Within a few hours, however, strangers are accepted as members of the group. Members of different species will live together amicably in laboratory cages and there is no evidence that antagonisms between the species are important in limiting the distribution of either one.

The rate of reproduction is highest in *maniculatus*, with an average litter size for wild and captive females of 5.00 young. The average size of litter for *truei* is 3.43, while *californicus* has the slowest rate of reproduction with an average litter of 1.91. All these rates of reproduction are high enough quickly to produce great overcrowding in local habitats if not controlled in some manner. Only scant evidence of predation on these forms in nature was obtained, although an invasion by weasels suddenly wiped out the populations of all three species of *Peromyscus* on one area. Many young *Peromyscus* are presumed to emigrate from their places of birth and occasional individuals were trapped up to distances of three-fourths of a mile away. It is probable that such emigrants often fail to find habitats suitable for their survival.

The treatment of the data on the growth of the individuals is particularly thorough. For other sections the presentation of more quantitative details would have been desirable, but would have considerably increased the size of the book.

In spite of the excellence of the information on life histories and behavior here presented, the factors that control the populations still elude us. No evidence was discovered of serious competition within or between the species for food or space. The differences between the species in behavior and in their requirements for existence seem slight to us, though, as the authors point out, these slight differences may be of great importance to the animals themselves. Many more studies, both in the field and in the laboratory undoubtedly will be required before we will discover the precise factors which enable each of these species to succeed in its particular habitat or which prevent it from living in other habitats which to us appear equally satisfactory.—LEE R. DICE, Institute of Human Biology, University of Michigan, Ann Arbor.

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IN THE NEXT ISSUE

- Revisionary Studies in the Ant Tribe Dacetini.....William L. Brown, Jr.
- Some American Millipeds of the Order Spirobolida.....Ralph V. Chamberlin
- On Five New North American Millipeds and Records of Some
Established SpeciesNell B. Causey
- Notes on the Spawning Population of the Freshwater Drum (*Aplodinotus
grunniens Rafinesque*) in Western Lake Erie.....Franklin C. Daiber
- Effects of a C-47 Airplane Application of DDT on Fish-food Organisms in Two
Pennsylvania WatershedsC. H. Hoffmann and A. T. Drooz
- On Certain Small Terrestrial Mammals That Are Alleged to Fish with the
TailE. W. Gudger
- A New Species of *Acanthocephala* from the Sunfish, *Lepomis gibbosus*
(Linnaeus), with a Re-description of the Family Fessitendidae
Van Cleave 1931A. James Haley and Wilbur L. Bullock
- Studies on Monogenetic Trematodes. XV. *Dactylogyridae* from Alaska,
Wisconsin, and Wyoming.....John D. Mizelle and Francis O. Webb
- Vegetation of Haven Hill, Michigan.....Paul Woodard Thompson
- Gross Modifications in Certain Plant Species Tolerant of Calcium
Sulfate DunesLora Mangum Shields
- The Taxonomy of *Halogeton glomeratus*.....George Zappettini
- A Revision of the *Choanephoraceae*.....C. W. Hesselatine

